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March, 1960

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A Simple Practical Method For Chart Control by the Operator

Manufacturing Quality Evaluation

Quality Engineering Applied to Incoming Material

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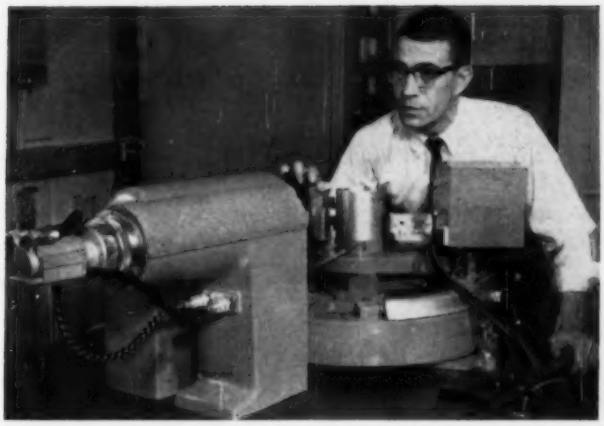

Chemist Jack Wright developed the use of this X-ray fluorescence machine for testing the concentration of preservatives in wood. Here he bombards a boring from a test telephone pole with X-rays.

This Bell Labs chemist is using a fast, new technique for measuring the concentration of fungus-killing preservative in telephone poles.

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INDUSTRIAL QUALITY CONTROL

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From the President's Desk

Another Milestone for Industrial Quality Control

This issue, March 1960, heralds another forward step for your Journal, *Industrial Quality Control.*

In the continuing efforts of your Officers, Board of Directors, and Editorial Board to improve the service of the Society to its members, steps have been taken to have the Journal reach you at the beginning of the month of issue, rather than late in the month. Heretofore, *Industrial Quality Control* has been printed between the 8th and 10th of the month and mailed on or about the 14th, with the result that approximately three-fourths of the month has passed before you receive your copy. The Journal is now being printed on the 22nd of the previous month, so that you will always have a current month copy of *Industrial Quality Control* available.

This change has been occasioned by a shift of printing operation to Publishers Printing Company of Shepherdsville, Kentucky. There appears to be a substantial saving involved in this new arrangement and we look forward to increasing the size of the Journal at an early date, with a corresponding increase in editorial content.

Your Society management groups shall continue these and other efforts to enhance the value of the Journal to the members of the Society.

C. E. Fisher

Quality Control in the Automatic Factory

AN Opportunity AND A Challenge

ALBERT B. BISHOP, *Ohio State University, Columbus, Ohio*

Introduction

In the light of accelerating present day trends toward automation of industrial and military production and supply, it becomes expedient for the quality-control engineer and manager to step back briefly from his current task of ensuring quality product to take a hard, realistic look at the future. The time has come to examine recent and projected advances in production technology in an effort to evaluate the role that quality control is to play in the factory of the future.

That the control of quality will assume ever-increasing importance is readily obvious. The growing complexity of products and higher unit costs caused by high taxes, wages, and overhead, make scrap too expensive to tolerate. A World War II bomber, consisting of about 2000 parts cost anywhere from $75,000 to $500,000. Today's supersonic attack bomber is made up of over 10,000 parts and sells for a phenomenal $3,000,000 or more. Not even an inflated economy can afford many rejects. Competition and market saturation, currently prevalent in several of our major industries, also act to make the selling of a "lemon" to an unsuspecting customer a disaster of far-reaching consequence.

It is generally agreed, therefore, that the control of product quality from the drawing board to the customer's office, shop, or home is of utmost importance to every manufacturer. "Total Quality Control" is here to stay. It is needed. *But*—what form must it take to be optimally effective? What technological developments will quality control as we know it today have to undergo to keep pace with advances in production and distribution technology? What can be and is already being accomplished along these lines?

ASQC LCS Codes 740:60;70:400
*Presented at the Minnesota section, ASQC, Industrial Clinic for Quality Control, Minneapolis, Minn., Feb. 19, 1959.

It is to these questions that the following discussion is directed.

Demands of an Automatic Factory

The effects of two factors which characterize many automatic processes are already being felt in certain areas of the quality control field. The first is the high production rate often obtainable by automation; the second is the emphasis on simplification and routinization of the component operations of the process needed to make automation feasible.

High production rates place a premium on the rapidity with which changes in process levels can

be detected and corrected. A typical cigarette-making machine rolls, glues, and cuts approximately 1200 regular-size cigarettes in a minute. Both mean and variance of the cigarette weight are critical factors for economic production and cutomer acceptance, and require almost continuous control. Using the best available automatic scale, trained operators, and computing aids, a minimum of three hours is required to compute the mean and variance of a two-minute sample of production. Inspection costs would be exorbitant if regular sampling were done on this basis. Also, if the process were operating improperly, a minimum of 216,000 unmarketable cigarettes would be produced before knowledge of the trouble could be detected. Obviously, control dependent on manual sampling, measuring, and data processing is an absurdity for such a process. Only with the development of β-ray detection devices and electronic variance computers has effective control been realized.

The point illustrated by this example is that to control a process effectively the measurement, calculation, and adjustment phases of the quality control function must take place at a speed comparable with that of the process being controlled. Often this can be done only by automatic measurement and feedback control. Furthermore, whether performed automatically or not, these procedures must be simplified and explicitly spelled out so they can be performed as rapidly as possible in a routine fashion.

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Simplification and routinization are also important in their own right. Routinization of control as well as production procedures is generally desirable for many reasons, foremost among which are: (1) a potential reduction in the number of errors made in effecting control and (2) economic savings permitted by utilization of less skilled labor and/or automatic devices.

If now, substantial benefits are to be gained from routinization and, to an even greater extent, from automation of the process-control function, it behooves us to determine what is required to accomplish these ends and what problems might accrue in so doing. Obviously, in-line instrumentation capable of providing essentially continuous measurements of critical process or product characteristics is essential. The aforementioned β-ray photo-electric cells, and a host of other devices which fall into this category are in use or being developed.

Another necessity of equal importance with that of proper instrumentation is the necessity for an explicit statement of rules on which to base control action once measurements have been made. It is not sufficient in automatic control utilizing either machine or human measurement and adjustment links to state "if a measurement falls outside this control limit, go look for trouble." A more explicit rule is required such as, "if a measurement equals x, make an adjustment equal to f(x)." Here x is a particular measured value of some process or product parameter and f(x) is a specific analytic or numeric function of x, which is either built into a mechanical control device or given to an inspector or clerk to dictate his actions. With this system, a unique control action is specified for any possible measurement x.

An Additional Problem

At this point an additional problem comes to mind. We are requiring an adjustment in the process to be made on the basis of a measurement x. Yet, industrial systems are characteristically complicated by the presence of significant random variations due both to the innate character of man-machine systems and to measurement errors. The measurement x is thus made up of two components, (1) the actual value of the parameter being measured and (2) a random error due to individual product differences, sampling, measurement, and the like. It is, therefore, possible that with such a control system a process which is operating exactly as desired could appear, due to a sampling error for instance, to have drifted significantly. An adjustment made in this situation would actually degrade system performance rather than improve it.

The question therefore arises as to whether complete automatic control of industrial processes is at all feasible, and, if so, what types of control system can be employed.

The intuitive and, as we shall see, the operational answer to the first part of the question is yes, automatic control is feasible and practical. The gun-laying radars and flight-control systems, long successfully controlled by standard servomechanisms, are all subject to some degree of random variation. The characteristics of the industrial

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process differ simply in degree and not in kind from those of the "deterministic" systems. The question is, therefore, not *can* control be effected, but how can *proper* control be effected and evaluated.

In the following sections one of the simplest classes of control system, the simple proportional controller, is studied and evaluated for certain potential applications. It should be kept in mind in reading these sections that the proportional controller is discussed not so much for its own sake (although it is in wide use) but primarily to illustrate the analysis and design procedures necessary to effect and evaluate automatic control of processes subject to significant random variations.

Simple Proportional Control of Random Processes

The simple proportional controller is discussed here because the principles to be set forth can be demonstrated most easily with respect to this controller. Proportional control also has wide intuitive appeal because each corrective action taken directly counteracts some or all of any observed deviation from desired operating levels.

A formal description of the operation of the simple proportional controller can be made as follows. Let m_k represent the deviation between the actual level of operation of the process being controlled and the desired or bogie level of operation. Individual items of product made at time k will, due to random variations inherent in the process, form a distribution around m_k. If one of these items is measured, an observed deviation from bogie, x_k, is obtained. The observed deviation has the following relationship with the actual system operating level

$$x_k = m_k + \varepsilon_k \tag{1}$$

where ε_k is a random variable representing the random variation of items of product around the actual process average. With the simple proportional controller, the adjustment to be made, $f(x_k)$, will be:

$$f(x_k) = ax_k \tag{2}$$

where "a" is the proportionality constant and is independent of "k". It is of course possible to base adjustments on the average of measurements made on several items of product, but since the analysis of such a system is essentially the same as the one described by equation (2), only the case of single measurement will be considered.

Let r_k be the net effect of all assignable causes affecting the level of process operation between times k and (k + 1). Therefore, assuming $m_0 = 0$,

$$m_1 = r_1 \tag{3}$$

$$x_1 = m_1 + \varepsilon_1 = r_1 + \varepsilon_1 \tag{4}$$

and

$$f(x_1) = ax_1 = ar_1 + a\varepsilon_1 \tag{5}$$

The level of operation at the second instant of time is, therefore,

$$\begin{aligned} m_2 &= m_1 + f(x_1) + r_2 \\ &= (r_1) + (ar_1 + a\varepsilon_1) + (r_2) \\ &= (a + 1)r_1 + r_2 + a\varepsilon_1 \end{aligned} \tag{6}$$

assuming the ε's and r's to be independent of each other. Similarly,

$$x_2 = m_2 + \varepsilon_2 = (a + 1)r_1 + r_2 + a\varepsilon_1 + \varepsilon_2 \tag{7}$$

and

$$f(x_2) = a(a + 1)r_1 + ar_2 + a^2\varepsilon_1 + a\varepsilon_2 \tag{8}$$

Thus

$$\begin{aligned} m_3 &= m_2 + a(x_2) + r_3 \\ &= (a + 1)^2 r_1 + (a + 1)r_2 + r_3 \\ &\quad + a(a + 1)\varepsilon_1 + a\varepsilon_2 \end{aligned} \tag{9}$$

Following this procedure, it is easily shown that

$$m_k = m_{k-1} + f(x_{k-1}) + r_k$$

$$= \sum_{i=1}^{k} r_i(1 + a)^{k-i} + \sum_{i=1}^{k-1} \varepsilon_i\, a(1 + a)^{k-1-i} \tag{10}$$

This relationship can be proven by mathematical induction.

It is apparent from equations (6), (9), and (10) that because of the presence of the random variable as a component of each adjustment, the level of process operation from time k = 2 on has a random component. Therefore, the process operating level is a random variable, the distribution

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of which is a joint distribution made up of a linear combination of the distributions of all random variables which have previously occurred. To evaluate the effectiveness of the controller, certain properties of the distribution of m_k, and, of even greater general importance, the properties of the limiting distribution approached as k increases without bound, must be determined. Attention will be restricted here to this limiting or "steady-state" distribution of m_k.

Ideally, one would like to know the specific probability density function of the steady-state distribution, and indeed such knowledge is required for design of optimal systems for specific applications. The general applicability of any class of control system, such as the proportional controller, can often be determined, however, from the usually more simple calculation of certain parameters of the distribution. Consider, for instance, the mean and variance of m_k, assuming for simplicity that all ε's are independently distributed with mean zero and variance σ^2 and remembering that in any given sequence of process operation the effects of assignable causes entering the process are fixed. Then:

$$\bar{m}_k = \sum_{i=1}^{k} r_i(1 + a)^{k-i} \tag{11}$$

and

$$\sigma^2_{m_k} = \sum_{i=1}^{k-1} \sigma^2 a^2 (1 + a)^{2(k-1-i)}$$

$$= \sigma^2 a^2 \sum_{i=0}^{k-2} (1 + a)^{2i}$$

$$= \sigma^2 a^2 \frac{1 - (1 + a)^{2(k-1)}}{1 - (1 + a)^2}$$

$$= \frac{-\sigma^2 a \left[1 - (1 + a)^{2(k-1)}\right]}{2 + a} \tag{12}$$

Note, (11) contains no ε-terms because the expected value of each is zero and (12) contains no r-terms because the r's are constants.

In considering the limiting values as k approaches infinity, we can, without loss of generality, restrict attention to the effects of the controller on a specific assignable shift, r_1. The effects on all other r's will be exactly the same but will lead or lag the effects on r_1 according to their occurrence time. We will thus consider the simplest case, a shift in operating level by an amount r_1 before the first observation is made and no subsequent shifts due to assignable causes. In this case,

$$\bar{m}_k = r_1(1 + a)^{k-1} \tag{13}$$

the limit of which as k approaches infinity is zero as long as

$$| 1 + a | < 1 \tag{14}$$

or

$$-2 < a < 0. \tag{15}$$

For

$$| 1 + a | > 1 \tag{16}$$

the limit is infinite, indicating a lack of useful control. This condition will result either in the

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What is the purpose of the workshop seminar? To explore in depth, tested methods of increasing the effectiveness of the quality control program in an industrial plant.

For whom is the program planned? For present and prospective Quality Managers. It is expected that the applicant will have reasonable familiarity with such standard texts as Grant, Feigenbaum, and Juran. To benefit properly from the seminar, the applicant should have a minimum of several years experience with major responsibility for quality.

Who will direct and conduct the program? The Director will be Paul C. Clifford, Professor at Montclair State College. Speakers and Discussion Leaders will include managers of outstanding quality control programs.

Registrants will be sent study materials and case studies prior to the conference. Registration is limited to 75 persons and is complete only on receipt of the registration fee of $100 which includes the cost of three lunches.

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activation of a safety switch or in the system destroying itself. For $a = 0$, no control is effected and all shifts remain unaltered. For $a = -2$, the process mean will oscillate back and forth between $\pm r_1$ until the process is shut down or a fatigue failure results.

The limit of the *variance* of m_k is found from (12) to approach $-\sigma^2 a/(2+a)$ for values of $(1+a)$ expressed by (14) and (15). For values of $(1 + a)$ expressed by (16), the variance would be infinite. The same can be shown to hold for $a = -2$. It can also be shown that zero variance results if $a = 0$, that is, if no random variation in the items of product is fed back into the process. It is thus apparent that only if

$$-2 < a \leq 0 \qquad (17)$$

will the limiting distribution of m_k have infinite variance. Should the variance be infinite, the probability of getting any individual item within any fixed band around the desired level of operation becomes zero regardless of the value of the mean of the distribution, so a finite variance is essential for a useful control system. Therefore, for a proportional controller to be at all useful, the proportionality constant must lie in the range specified by equation (17). A determination of this so-called "stable range" is usually a first step in the design or evaluation of any type of control system.

Selection of Optimal Controller

Having determined the range of values of "a" resulting in stable system operation, it is now necessary to select a specific value to be used. The "best" value can of course be arrived at only with respect to a specific process to which specific performance criteria apply, but some general techniques for relating system parameters to the applicable criteria can be developed. One such technique is presented here for illustrative purposes.

Consider the case in which the output of the process is categorized as acceptable or defective depending on whether or not it falls between specified tolerance limits. This case is very common in industrial production systems. Scrap or rework costs are incurred whenever an item of product falls outside limits, regardless of how *far* out it falls. Likewise, no differentiation is made among parts falling within limits. They are all "good" and can be used directly in subsequent operations.

Let the upper and lower tolerance limits be T_U and T_L units, respectively, above and below the specified process mean. Recall that there is a distribution of individual items around the actual process mean due to the random nature of the manufacturing process. For simplicity, let us assume that

1. measurement errors are negligible relative to normal random variations in the process itself and,
2. normal process random variation is normally distributed with mean zero and a constant variance of σ^2.

Under assumption 1, ε_k describes the variation of x_k around m_k. Under assumption 2,

$$\varepsilon_k = N(0,\sigma^2) \qquad k = 1, 2, \ldots, \infty \qquad (18$$

Recall also that as a result of our control action, m_k is randomly distributed. The probability function of x_k is, therefore, the joint density of m_k and ε_k. From equations (1), (11), and (12) it is apparent that

$$\overline{x_k} = \overline{m_k} + \overline{\varepsilon_k} = \overline{m_k} + 0$$

$$= \sum_{i=1}^{k} r_i(1 + a)^{k-i} \qquad (19)$$

and

$$\sigma^2_{x'_k} = \sigma^2_{m_k} + \sigma^2_{\varepsilon_k} = \sigma^2_{m_k} + \sigma^2$$

$$= \sigma^2 a^2 \sum_{i=0}^{k-2} (1 + a)^{2i} + \sigma^2$$

$$= \sigma^2\left[a^2 \sum_{i=0}^{k-2} (1 + a)^{2i} + 1\right] \qquad (20)$$

In the limit, the variance of x_k as expressed by (20) becomes

$$\lim_{k\to\infty} \sigma^2_{x_k} = \sigma^2\left[\frac{-a}{2 + a} + 1\right]$$

$$= \frac{2\sigma^2}{2 + a} = \sigma^2_z \qquad (21)$$

for "a" within the stable range.

Let "p" equal the maximum fraction defective we are willing to tolerate under normal conditions, i.e., in the absence of assignable causes. Some fault may be found with the realism of this criterion, but this is exactly analogous to the procedure used to set limits on control charts. With no shifts due to assignable causes, all the r's are zero and x_k is zero for all k. The fraction defective, therefore, is determined solely by the spread of the distribution of x_k, which is measured by the expression in (21). From (21), it is obvious that as "a" becomes more negative (moves from zero toward −2) that σ^2_z (the limit of σ^2_{xk}) increases. Therefore, the specified T_U, T_L, and "p" impose a limit on how negative "a" may be.

It can be shown that with the ε's normally distributed, the steady-state distribution of x_k is also normally distributed. Therefore, to determine the limit on the negativity of "a", let $Z_{0.5p}$ be the distance in standard normal deviates from the mean of a normal distribution to the point below which $(1 - p/2)$ of the distribution falls. (This assumes symmetrical tolerance limits. If the limits are not symmetrical, a conservative approximation can be made considering the limits to be symmetrically placed at a distance from the mean equal to the tighter of the two given limits. Another approximation would be to average the distances. Otherwise, more complicated procedures must be used.)

This $Z_{0.5p}$ is the minimum allowable number of standard deviations between the mean and either tolerance limit. Should σ^2_z be large, the *number* of standard deviations of the limiting distribution of x_k between tolerance limits will be too small and the resulting fraction defective will be too large. Thus,

$$T_U \text{ (or } -T_L) = Z_{0.5p}\,\sigma_{z\,max} \qquad (22)$$

Since $\sigma_{z\,max}$ occurs for a_{min} (most negative), we can substitute (21) in (22) and solve for a_{min}. The resulting expression is

$$a_{min} = \frac{2(\sigma^2 Z^2_{0.5p} - T_U^2)}{T_U^2} \qquad (23)$$

for "a" within the stable range.

Equation (23) specifies a lower limit for "a". The actual value of "a" to be chosen within this (and the stable) range can be determined by considering the action of the control system in eliminating assignable causes. Table I gives the expected fraction of any given shift, r_i, remaining after one, two, three, and an infinitely large number of ensuing corrective actions. From the table it is observed that, on the average, each shift is immediately eliminated for a = −1. For "a" between

TABLE I–Characteristics of Simple Proportional Control Systems

a	$\frac{\sigma^2_z}{\sigma^2}$	Fraction of r_i remaining			
		1 adj.	2 adj.	3 adj.	n→∞ adj.
−2	∞	—	—	—	—
−1.8	10.00	−0.8	0.64	−0.512	0
−1.6	5.00	−0.6	0.36	−0.216	0
−1.4	3.33	−0.4	0.16	−0.064	0
−1.2	2.50	−0.2	0.04	−0.008	0
−1.0	2.00	0	0	0	0
−0.8	1.67	0.2	0.04	0.008	0
−0.6	1.43	0.4	0.16	0.064	0
−0.4	1.25	0.6	0.36	0.216	0
−0.2	1.11	0.8	0.64	0.512	0
0	1.00	1.00	1.0	1.0	1.0
>0	∞	—	—	—	—

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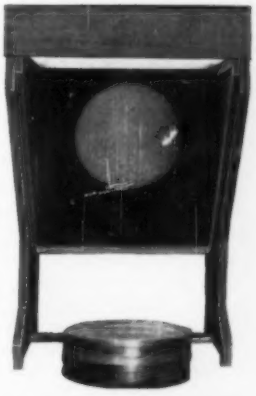

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zero and −1, the shift is corrected a piece at a time. For "a" between −1 and −2, over-corrections are made which drastically increase $\sigma^2\infty$ but do not eliminate the effects of the shift immediately (although they reverse its direction periodically). Thus, unless we are trying to anticipate a future assignable cause, we would never choose an "a" more negative than −1 but would get as close to −1 as possible. We therefore, adopt the following rule:

1. Compute a_{min} from equation (23)
2. If (1) $a_{min} \leqq -1$ use $a = -1$
   (2) $-1 < a_{min} \leqq 0$ use a_{min}
   (3) $a_{min} > 0$ discard process and/or revise specifications; the present process is incapable of meeting specifications.

We can, therefore, for the situation cited find an optimal value of proportionality constant for any specified T_U, T_L, p, and known σ^2.

More complex systems often require more involved procedures, especially non-linear devices such as dead-bands. Some work has been done for a proportional controller with dead-band, utilizing a Monte Carlo simulation on an IBM 650. Preliminary results indicate that steady-state variance is minimized for any given value of "a" with a dead-band of between one and two sigma. These results are of special interest because of the similarity between dead-band controllers and the common control chart.

Conclusion

An attempt has been made in this paper to point out the demands being placed on the quality control function by automation in industry. The high production rates and the desirability of simple routine operations are placing increasing emphasis on in-line instrumentation and automatic feedback control. The random nature of most industrial processes introduces some problems in the design of automatic control systems not normally critical in classical control-system design. These problems are primarily concerned with determination of the relationships between the control-system constants and the statistical parameters of the distribution of process output. The simple proportional controller was utilized to illustrate the establishment of such relationships and their use in determining optimal control systems.

This discussion has been presented in the sincere belief that automation is going to have a marked effect on quality control. There is every reason to believe this effect will be extremely beneficial. The demands imposed by automation are creating the very conditions which can vault quality control into heretofore almost unhoped for heights of responsibility and prestige. To realize the full potential of the opportunity being presented, however, the perspective, concepts, and techniques of the quality control engineer will have to be broadened and expanded. It is hoped the discussion herein might arouse some interest in the problems of automatic control and indicate the general direction in which the field must develop to meet the challenges being imposed.

A Simple Practical Method

WILLIAM C. BAUER
The Stanley Works, New Britain, Conn.

Introduction

The mention of statistical quality control and control charts, unfortunately often conjures mysterious symbols, complex formulas and phrases to the would be users of these tools. This proposed method for chart control is directed to those people willing to settle for a simple charting procedure that will give the operator a visual guide for action but who are not interested in the question of statistical stability in the sense of standard Shewhart control charts.

Theory and Formulas

This method uses chart limits based on specification limits, rather than specification limits based on control charts or process capabilities.

TABLE I–Factors

Sample Size	1/6 $\tilde{A}$	1/6 D_1	1/6 D_2
2	0.353	0	0.614
3	0.336	0	0.728
4	0.273	0	0.783
5	0.269	0	0.821
6	0.232	0	0.846
7	0.231	0.034	0.869
8	0.201	0.065	0.844
9	0.207	0.091	0.901
10	0.203	0.114	0.912

To start we assume a normal distribution whose spread of plus and minus three standard deviations is just equal to the tolerance limits. This distribution would be the largest spread which would be acceptable with each standard deviation equal to 1/6 of the total blueprint tolerance (TBT). With the value of one standard deviation set at 1/6 TBT, and using the formulas and factors found in Grant*, we find:

$UCL_R = D_2\sigma'$ or $UCL_R = 1/6\ D_2$ (TBT)
$LCL_R = D_1\sigma'$ or $LCL_R = 1/6\ D_1$ (TBT)

Again using $\sigma' = 1/6$ TBT and formulas and factors found in Clifford's "Control Charts Without Calculations"†

$$UCL_m = \overline{X'} + 1/6\ \tilde{A}\ \text{(TBT)}$$

$$LCL_m = \overline{X'} - 1/6\ \tilde{A}\ \text{(TBT)}$$

Where $\overline{X'}$ = Blueprint nominal, subscript m refers to sample median. Table I shows values of 1/6 $\tilde{A}$, 1/6D_1, 1/6D_2.

ASQC LCS Code 111:70:400
*Eugene L. Grant, *Statistical Quality Control*, First Edition, McGraw-Hill, New York, Appendix III Table E, p 539.
†Paul C. Clifford, "Control Charts Without Calculations", *Industrial Quality Control*, Vol. XV, No. 11, May 1959.

For Chart Control

By the Operator

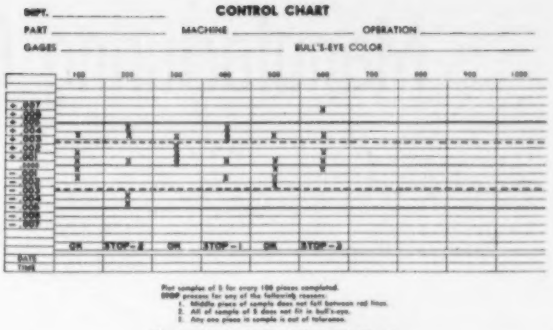

Figure 1—A Typical Control Chart

Note: On these charts, as used in the shop, the broken lines for limits on the median are plotted in red. The bull's-eye for controlling range is not shown.

Mechanics

Now that limits for the chart have been established, we have only to contend with the preparation and use of the chart. A typical chart is shown in Figure 1.

A. To prepare the control chart:
   1. Place the blueprint tolerance on the left side of the card with equal increments of tolerance above and below the target or zero line.
   2. Extend the upper and lower blueprint tolerance limits horizontally to the right with a solid line.
   3. Extend the upper and lower control limits for median to the right with a broken line.
   4. Select the proper "bull's-eye." The "bull's-eye" is a rigid circle whose inside diameter is equal in magnitude to the UCL_R as measured in units of the control chart.

B. The control chart is used by the operator as follows:
   1. Measure each piece of the sample and record these measurements by a series of marks in a vertical row in the first vertical column.
   2. Repeat Step 1 in the following column.
   3. Continue production if the process is satisfactory. The process is satisfactory if:
      a. The median of each vertical row is between UCL_m and LCL_m.
      b. The entire sample fits within the "bull's-eye", which is the range upper control limit.
      c. All pieces fall within the upper and lower blueprint tolerances.*
   4. Note any gradual shifting of the sample and reset before production is actually unsatisfactory.
   5. Stop production if the process is unsatisfactory. The process is unsatisfactory if any *one* of the following occurs:
      a. The median of any vertical row is outside the UCL_m or LCL_m.
      b. The entire sample does not fit within the "bull's-eye".
      c. Any piece falls outside the blueprint tolerances.*

*Although these pieces are unsatisfactory, technically if pieces fall within or outside of blueprint tolerances, it is not a valid indication that the process is out of control. Therefore, if so desired, the process may be examined by making it over into a control chart of the type discussed in Clifford's "Control Charts Without Calculations."

Advantages

The advantages of this proposed chart are:
1. Only one chart is necessary rather than the customary two.
2. It has simple understandable range control in the form of a "bull's-eye".
3. No computation is required by the operator.
4. No need for setting and readjusting control limits.
5. Charts and "bull's-eyes" may be mass-produced, complete with both mean and blueprint tolerance limits for popular tolerances such as ± 0.003, ± 0.005 and ± 0.010.
6. If specification limits are wider than process limits, economical long-term operating conditions become possible.

Western Regional Conference Council To Stimulate Convention Attendance

R. Calvert Haws, president, Quality Control Engineers, has recently been elected chairman of the Western Quality Control Conference Council of the American Society for Quality Control.

To encourage attendance at the 14th Annual Convention and Exhibition, Hotel Sheraton-Palace, San Francisco, Calif., May 24-26. Mr. Haws is presently engaged in appointing booster committees in each of the twelve West Coast sections, excepting San Francisco, to obtain as large an attendance as possible for this important convention.

In the 15 year history of ASQC, there has never been a Convention on the West Coast. Included in the program will be panel discussions and outstanding speakers. Rudolph F. Bannow, president of NAM, will deliver the keynote address.

The military will be fully represented at the Convention.

Manufacturing Quality Evaluation

JOHN SCHNEIDER, *IBM, Owego, N. Y.*

GLENN A. WILCOX, *IBM, Endicott, N. Y.*

The emphasis on a quality product is becoming more paramount throughout industry. Actually, a high quality product, economically produced, is the goal of all manufacturing. In order to achieve this goal, adequate quality controls are needed during all phases of manufacturing.

In its broad sense, quality control is the mechanism by which products are made to measure up to specifications determined from customers' demands and transformed into sales, engineering and manufacturing requirements. It is concerned with making things right rather than discovering and rejecting those made wrong. To accomplish this, a method of indicating the degree of control is necessary. This method will indicate the measure of quality obtained and point out areas for improvement. This method also becomes a system of evaluating the quality within a manufacturing facility that is vigilant.

ASQC LCS Codes 112; 352; 720:70:400

Machining Function

Quality is controlled in the Machining Division of IBM Endicott by an operator-audit plan of inspection. In this system the operator controls quality at the process point, thus reducing the manufacture of defective parts. An audit is performed by an inspector simply to monitor quality.

The proper and fair evaluation of the quality produced within a department is accomplished by using information

QUALITY EVALUATION (Machining) Month of JUNE 1958 Manager J. P. JAMES Dept. 001

Standard for JULY 1958 Average ($\bar{p}$) 98.85 Limit 97.82

NO. PARTS INSP.	NO. PARTS DEF.	Week Ending
951	0	
839	0	
750	2	
936	19	
1087	16	6-6
1000	8	
1670	6	
1099	36	
908	15	6-13
1001	10	
733	2	
972	7	
1072	12	
1616	3	6-20
770	9	
623	3	
861	3	
875	18	
764	28	6-27
781	17	
1190	0	
20398	230	TOTAL

AVERAGE 98.92%

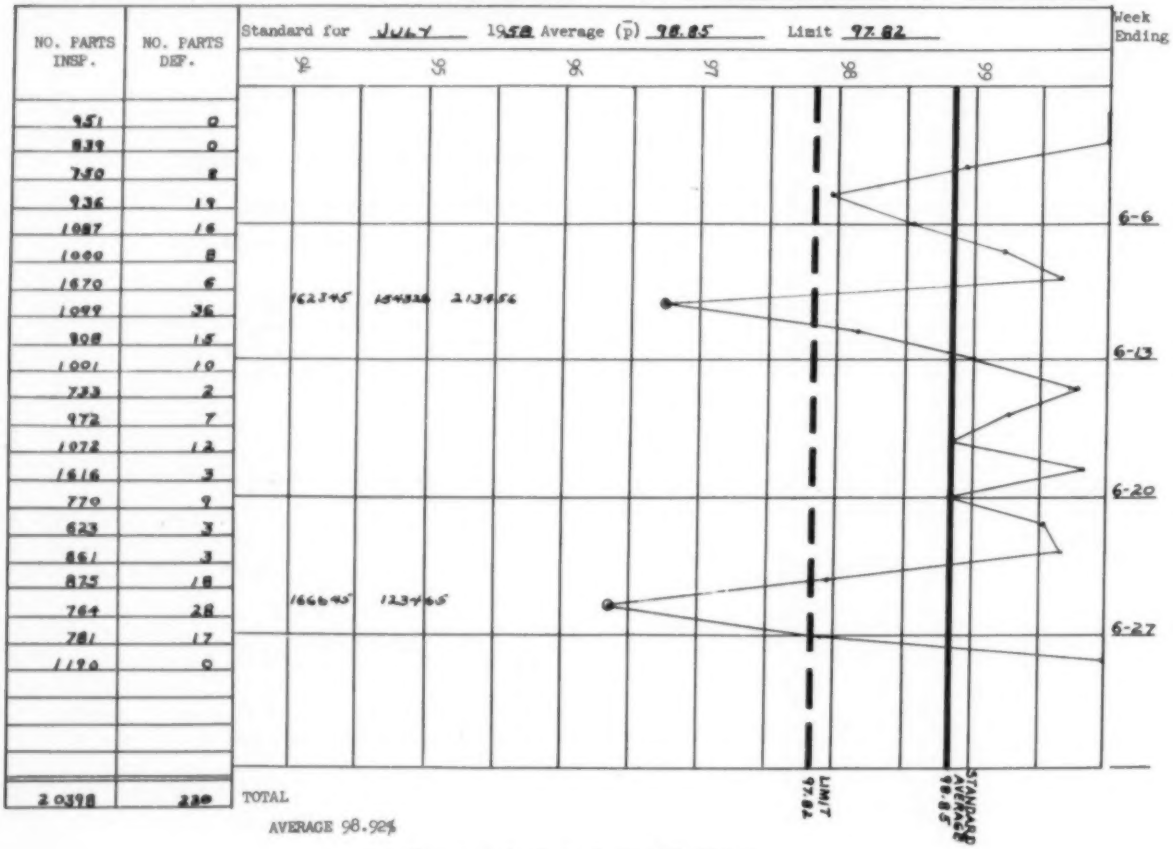

Figure 1—Quality Evaluation (Machining)

taken from the audit inspector's records. This means that all defective parts discovered by the operator and corrected by him are acceptable. Parts made to off-specifications granted to the operator are acceptable if they comply with the off-specification tolerances. Parts rejected by the audit inspector and accepted by a correction or an off-specification following the audit inspection are considered as defective parts for the evaluation.

The evaluation is performed by making a comparison of the present quality performance. The comparison is accomplished by determining the average percent compliance. This average percent compliance is similar to the $\bar{p}$ of a p chart. By subtracting p from 1 and converting into a percentage form, the average percent compliance would result. We have found that it is psychologically advantageous to use the percent compliance rather than the percent defective.

The average percent compliance of past quality permits us to establish limits for each day's quality performance. This limit is furnished in advance of the period being evaluated. Each day's quality must come above this limit. When the percent compliance of a day's production is below the limit, it is considered that the operation ran out of control.

The average percent compliance should be re-evaluated periodically based on more current experience. Improvements in the respective departments may raise their individual limits. It may be determined that a limit is too difficult to maintain, resulting in excessive sort, rework, and scrap costs. A thorough investigation should be made for corrective action before any limit is reduced.

Reporting and Taking Corrective Action

The inspection results are accumulated daily from each department for the preceding day, and the respective percent compliance for that day is computed and plotted on each department's chart. (See Fig. 1). Should an operation plot out of control, the department manager is immediately notified in writing, giving the part numbers which caused the out-of-control condition. The manager must note the cause and corrective action taken and forward a copy to his project manager. The Quality Control Division follows this action to determine the effectiveness of the corrective action.

At the end of each month a chart of the daily quality performance, Fig. 1, is issued to personnel concerned by the Quality Control Division. This chart is a pictorial presentation of the past month's quality history. This chart is a concrete tool with which to guide the Machining Division in its corrective action.

It is interesting to note that when a manager improves his quality, a new conformance value should be computed resulting in ever tightening controls until each department has found its level of quality where the percent conformance will remain consistent.

Another very interesting point to note is that the percent compliance of the past which we are using as a comparison need not be at a desirable high level. It is sufficient that it is determined and listed so that the manager is aware of it. This is founded on the premise that everything is in a state of change. We find it difficult to remain constant. Quality is either improving or degenerating. It is actually more

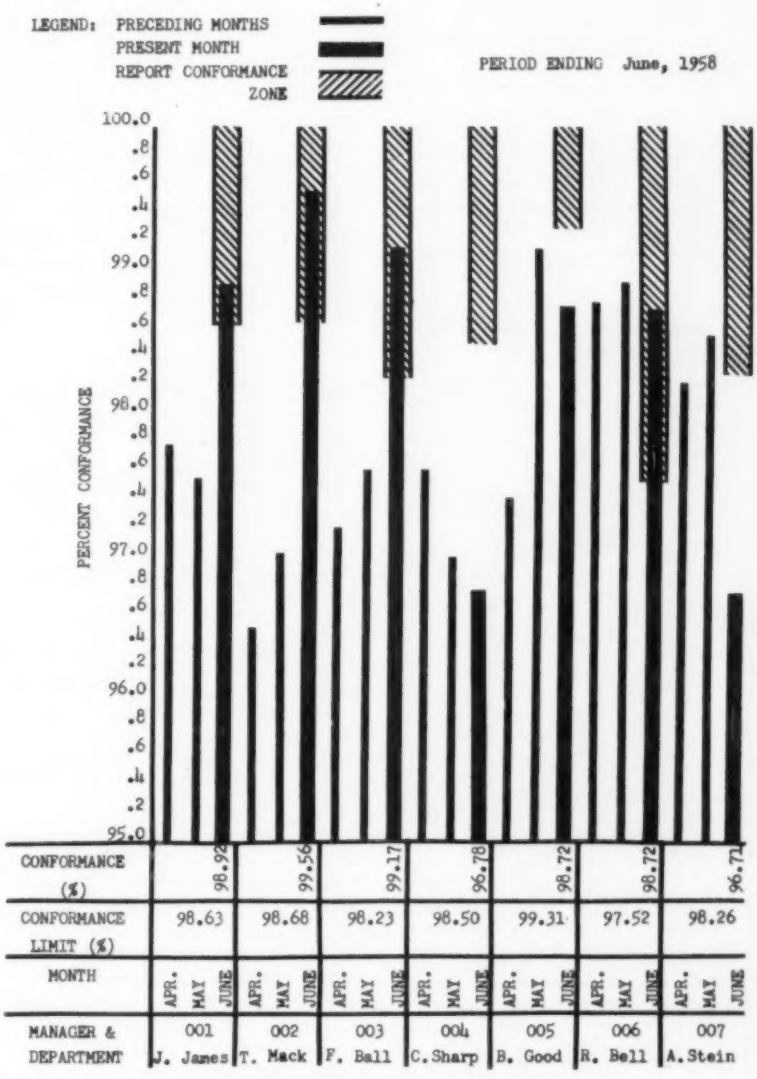

Figure 2—Manager and Department Quality Trend Percent Conformance (Machining)

difficult to maintain exactly the same quality than it is to improve it. With this premise in mind, we can see that if a low percent compliance is found, we will be raising it by improving the quality effort used in producing the product. This quality effort consists of better supervision, more care by the operator, realistic routings and specifications, and the host of intangibles that create a desirable atmosphere of good quality productivity. Since this premise is more true than not, the manager with a low percent compliance will improve his work to the point where further improvement is governed by economics. The procedure tells the manager his place in the quality picture, and where he can direct his efforts to make quality improvements.

Figure 2 is a summary and trend chart for the entire Machining Division. This chart is based on monthly data with the result of a different set of limits. This chart tells top management which department needs attention. The reporting month's quality is depicted by a wide solid bar, its limits by a cross-hatched bar, and the two preceding months by narrow solid bars. The two preceding months' bars are included to indicate the quality trend of each department. This chart is presented to the General Manager, completing the chain of reporting.

The computations of Fig. 2 are very similar to Fig. 1 The exception is the value of n which is the number of pieces inspected during the month. The solid bar is computed by dividing the total defective parts found during the month by the total pieces inspected during that month. This number is subtracted from one, and converted into a percent by multiplying by 100.

The cross-hatched bar is computed from formula (3), using the total number of pieces inspected during the month. The bar is extended from the value computed to the 100 percent line for comparison and presentation purposes.

Computations

The average fraction defective, $\bar{p}$, is computed by the formula

$$\bar{p} = \frac{\Sigma \text{ defectives from past experience}}{\Sigma \text{ pieces inspected in the past}} \quad (1)$$

The average percent compliance is computed from the formula

$$\text{Average percent compliance} = (1 - \bar{p})\,(100)$$

The general formula for fraction defective limits is derived from the binomial:

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}\,(1 - \bar{p})}{n}} \quad (2)$$

Care should be taken in using limits computed from the binomial. Remember that the binomial assumes a constant probability of occurrence of whatever events are under consideration.

The percent compliance limit, therefore, is one minus the fraction defective limit and multiplied by 100 to convert it into percentage form. Expressed by a formula, this becomes

$$100\left[1 - \left(\bar{p} + 3\sqrt{\frac{\bar{p}\,(1 - \bar{p})}{n}}\right)\right] \quad (3)$$

where n is the daily number of pieces inspected.

If there is little fluctuation of the number of pieces inspected from day to day, the limits may be computed by using the average daily number of pieces inspected. There may be instances where a constant limit will not apply because of fluctuations of the quantity of pieces inspected. This difficulty is eliminated by considering the limit lines as guides, and if a point plots on or near the limit, the limit should be recomputed for that day. Thus the proper proximity of the point to the limits may be determined and illustrated on the chart.

The only theoretical difficulty with the $\bar{p}$ chart approach on the limits is that the binomial distribution assumes constant probability. We can disregard this because the procedure as demonstrated in this article realizes that this probability is constant enough on an empirical basis so that it works well.

Summary

The gist of this procedure is to reveal a means of evaluating and reporting quality of a manufacturing activity. The evaluation is accomplished by making a statistical comparison between an established quality standard and the quality currently produced. This evaluation is confined to the individual manager's area of quality responsibility, thus promoting an incentive for each manager to improve his quality status. This evaluation pinpoints areas of concern and indicates when and where corrective action is necessary.

The system's strongest point is the shortened time span between discovery, notification, and corrective action. It strengthens the incentive to do quality work, thereby reducing costs of rework, scrap and sorting. It also assures the meeting of shipping schedules and stimulates customer acceptance and confidence due to the resultant good quality.

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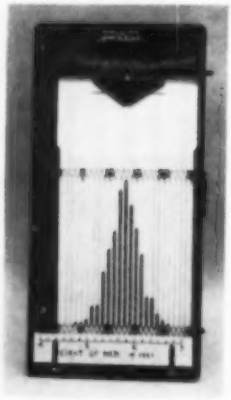

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QUALITY ENGINEERING

Applied to Incoming Material

DAVID A. HILL

Hughes Aircraft Co., Culver City, Calif.

Introduction

Quality engineering applied to incoming material is an important segment of the approach that A. V. Feigenbaum has called Total Quality Control.[1]

Incoming material refers to any kind of material purchased by an organization from suppliers—whether paper clips or ocean liners. As you may readily see, special circumstances that arise from this broad range of products cannot be covered in this paper. It follows that this discussion will not cover the problems of running an incoming inspection operation. The emphasis will be on quality engineering.

The author takes the stand that the entire incoming inspection operation is an excessive cost and that it is our duty to work toward abolishing it. The various approaches or programs that have been tried in recent times will be examined from this rather arbitrary viewpoint. During this examination some principles will be derived that can be applied by quality engineer to many situations. The ideas presented arise from the deliberations of the ASQC Committee on Professional Development, the study of published material and beliefs based on personal experience.

Some insight as to why the author is taking this position on incoming inspection may come from dropping in on such an operation. It is late afternoon on a Friday, the 27th day of September. The quality manager enters.

ASQC LCS Code 351:40:000

He has just made his way down from the shipping area, where he has been trying to light a fire under the final test and inspection operations.

Somehow half of the month's production always has to be squeezed through in this last week. The big boss has had colorful things to say about meeting schedules.

Now the Fun Begins

The quality manager calls the supervisor of incoming inspection out of his office and they head for the salvage crib, where suspended material is held for disposition. He picks his way among the crowded skids and the shelves packed with cartons, each dangling its tag of deceptively cheerful red.

Editorial Note

This article by Mr. Hill is the fourth in the series of "Professionalism in Quality Control," articles which are being presented by *Industrial Quality Control*.

MEW

Where, he wants to know from the supervisor, are the forsaken widgets from Creep, Inc. Final assembly is stopped dead. There are no widgets to replace the ones that have failed in final test.

The supervisor tries to locate the widgets. No luck. An inspector is summoned to find the shipment, does so promptly and hangs around to watch the fun. The quality manager snatches the Receiving Record. The shipment was inspected to the new weighted - demerit, truncated-sequential, three-severity level sampling plan. Not without some difficulty, to judge by the various scratchy revisions on the record of sample sizes and allowable defect numbers.

Item: two units undersize on keyway. That means rework on the night shift after the shipment is screened 100%.

Item: one unit, shaft torque over tolerance. Hopeless. That will have to go back. Are there others like it in the shipment? The torque test takes time.

Also, the shipment is rejected for excessive minor defects.

As the quality manager stands debating whether the night shift inspection can handle screening the widgets, whether the shop still has that pick-up tool for keyways, whether to compromise on the minor defects, he sees out of the corner of his eye that Old Leatherlungs, the production superintendent, is storming down the aisle. The quality manager sighs. From the dull red of Old Leatherlung's face he might as well prepare for the usual animated discussion of how Quality Control goes out of its way to find some fly speck faults every time a shipment is badly needed.

Let us draw a curtain on this unhappy scene and repair to some quiet place, removed from the strain and noise of production effort—say, to the quality engineer's office. The quality manager is in for it anyway. We will leave him to his problems and think about why they came about.

In contrast to what we have just seen, what would be the ideal? Would it not be wonderful to get our widgets from a really competent outfit, one with a solid record of quality, whose product gives us so little trouble we can put shipments directly onto the storeroom shelf? This cuts the cost of inspection for fair; never mind fancy sampling plans. Screening and rework will not hold up production. No more time spent arguing with purchasing about returning parts, faster corrective action and who pays for rework. No more debates about whether we or they measure torque correctly. An impossible ideal? Maybe. But are there some steps to be taken in that direction?

Sampling Plans Not Enough

The scene in incoming inspection suggests that statistical sampling plans for incoming inspection are not the final answer. This is not to depricate the wide variety of sampling techniques. They do a job up to a point but they all suffer from an inescapable limit: if the required quality level is 1% defective and the material is 1.01% defective our hopes of economizing go up in smoke.

Returning shipments to the supplier does not really change this. In the long run any supplier must recoup from his customer the cost of material returned or go out of business.

In addition, when we are working in incoming inspection, we have lost two of the most powerful advantages of true quality control. First, the sequence of production is generally lost. Second, the control is too remote from the source of variations.

We may be able to agree with A. F. Cowan on Acceptance Sampling, "But this is not quality control. It is application of statistical methods to inspection."[2]

Vendor Rating

How about vendor rating? Again a wide range of plans have been adapted to various needs.[3,4,5,6] They can provide for the relative importance of different kinds of defects. They compare supplier performance against a required standard. They can be simple, if that is what will do the job, or comprehensive enough to cover many hundreds of suppliers to a major program.

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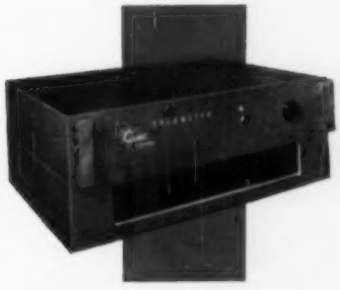

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Weapon System Management for Quality
Panel: Management's Concept of QC Responsibilities
The Measurement and Specification of Product Abilities
The Theory of Experimental Designs
When Is a Small Sample Large Enough?
Planning for Incoming Materials Control
SQC Applications in the Food Industry
The Quality Assurance Management Approach to Supplier-Consumer Problems
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Taste Testing
The Technologies of Total Quality Control
How Many Dollars Are There in Incoming Materials Costs?
Sampling Techniques for Corrugated Shipping Containers
Total Quality Control and Reliability
A Plan for Simplifying Trouble Analysis Reporting
Applicability of Quality Control Techniques to Telephone Subscriber Forecasting
The Course Ahead in Professional Development
QC in Textiles
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Between times, you will be thrilled by a sight-seeing trip around the island of Oahu or to Mt. Tantalus, where you will see Pearl Harbor, and the colorful and traditional Imu ceremonies on the oceanside of the Hawaiian Village Hotel, your home in the Islands for six nights.

Many other side trips, including flying trips to the nearby islands, will be available for you to take.

Colorful folders describing the Mid-Pacific Conference in Hawaii—our 50th state—may be obtained by writing to ASQC, Travel Secretary, c/o United Air Lines, 36 S. Wabash Ave., Chicago 3, Ill. Reservations are now being made at the Society's Headquarters, 161 W. Wisconsin, Milwaukee 3, Wis., for either or both meetings.

MISS HAWAII, Gordean Lee, who was chosen "Miss Congeniality" in the 1959 Miss America contest, shows some of the charm of our 50th state to William P. (Bill) Youngclaus, your ASQC administrative secretary, while on a recent visit to Milwaukee. She also graciously consented to demonstrating proper hula form.

You, too, will be thrilled by the charm of the Islands if you attend the Mid-Pacific Quality Control Conference in Honolulu May 27-June 2, immediately following the 1960 Convention of ASQC in fabulous San Francisco, May 24-26.

When volume justifies, the engineer can eliminate repetitious calculations by cranking the factors into data handling equipment.

Now we are getting a little closer to the benefits quality engineering can bring. The rating determines whether a supplier's product may be safely accepted after a minimum check —even skipping inspection on some lots altogether. Rating plans send up signals that corrective action is needed. An unfavorable trend over several lots is a stronger basis for action than trouble with an isolated shipment. Statistical techniques can increase the sensitivity of the index.

At this point I would like to plead for the conscientious supplier. To tell him only that his deliveries for the last month were "unsatisfactory" or that some excessive number of defects was found, and stop there as some do, is simply frustrating. He needs the details of tests and measurements that provide clues to work on.

Figure 1 show the spread of ratings for a large number of suppliers to one of our major divisions. On the charts A, B, and C vendors range from outstanding performance to acceptable; S vendors are required to demonstrate corrective action; X vendors have failed to respond to request for action. Their orders are cut off unless the quality manager makes a specific exception.

The quality performance index provides a guide to the selection of vendors for future orders. The quality engineer will have to realize that purchasing must also consider other factors, such as the ability to make deliveries on schedule at a favorable price.

Buyers are often abused by quality people for always taking low bid. If I were a buyer that is exactly what I would do until someone gave me sound evidence that the low bid was offset by the costs resulting from rejections, rework and customer complaints.

The vendor rating systems referenced above are based principally on the results found in incoming inspection.

This is far from being all that we can learn about vendor performance. In fact, it can be misleading if we do not take into account what happens after the part has been accepted by the normal incoming inspection process.

Occasional samples may be subjected to laboratory requalification tests that are more searching than normal incoming practice. There is the rework or rejections his material may cause during the manufacturing operations. Field troubles or customer complaints are a further clue.

Such data do not fit handily into statistical rating schemes but are much too important to be left out of the total picture of vendor performance.

Source Selection

Rating plans, like acceptance sampling schemes, also have a limitation. They depend on accumulated experience. The fat may be sizzling on the fire before we are warned of trouble. This suggests the value of looking over new sources.

Careful buyers check a supplier's ability to produce and his financial position before placing orders. There is no reason why his organization, equipment and procedures for controlling product quality should not be examined. This needs to be a lot

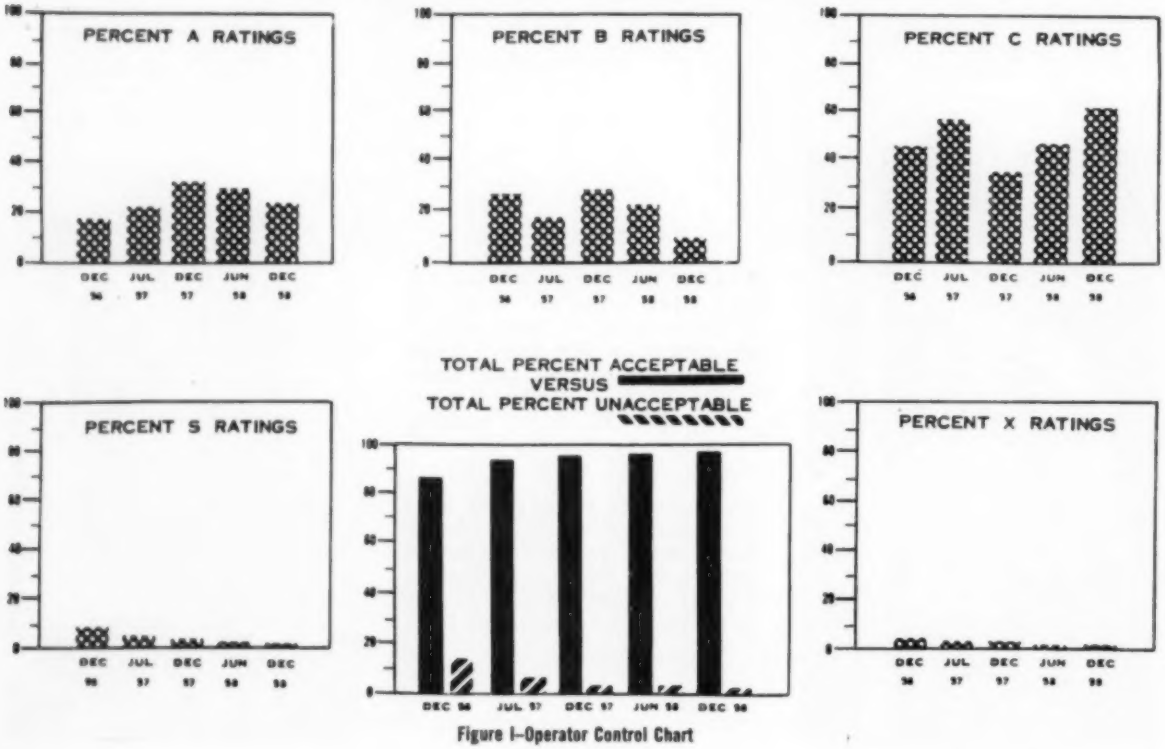


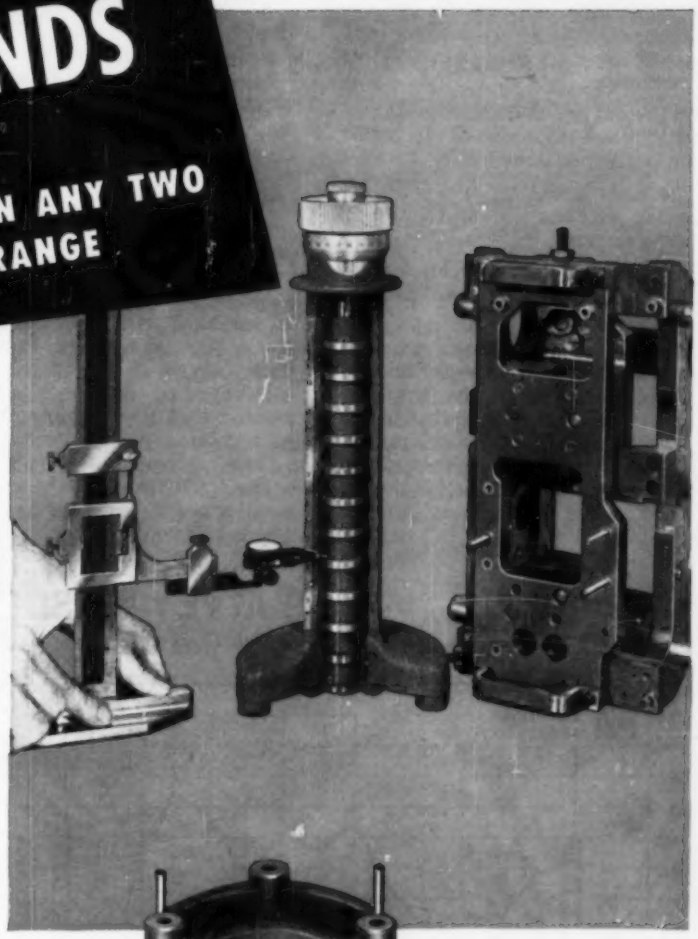
Figure 1–Operator Control Chart

SETTING TIME:

10 SECONDS

ACCURACY:

.00005" BETWEEN ANY TWO POINTS IN 12" RANGE



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Check lists can be designed for every variety of producer from buttonhole stitchers to jet engine manufacturers. They can cover very specific points. Some examples:

(1) what evidence is available that test equipment is calibrated on a planned schedule?

(2) does the supplier keep records of chemical and physical tests on raw materials?

(3) how does he withhold discrepant material from the flow of production.

There are occasions when it would be legitimate to ask for demonstration that the supplier's tooling is inherently capable of holding required tolerances. More than once our surveys have turned up the fact that a supplier did not even possess the equipment needed to demonstrate that he was meeting some requirements of the specification.

Reports need to be systematic and follow up positive on any discrepancies noted. Figure 2 charts the survey activity for a major Hughes division. Figure 3 shows the principal issues that turned up as problems. This vendor survey procedure can increase the chance of entering into a mutually profitable relationship.

I do not want to give the impression that purchasing departments will necessarily welcome at once this added complication in making procurement decisions. We have found, however, that they will accept a survey plan once it has been demonstrated that their problems with unsatisfactory sources can be reduced. Once again we have moved a little closer to genuine quality engineering by using our heads to avoid trouble.

Again I would like to make a plea on behalf of suppliers. We quality control people are as apt as the next fellow to become arbitrary in our outlook. Our survey may reject a supplier because he does not conform to preconceived ideas on what constitutes a proper quality system.

I have in mind a manufacturer of complicated and critical devices that go into advanced weapons systems. Our conscientious purchasing group was writing him stiff letters about the unsatisfactory results of quality's surveys. Since this was an important source, a visit seemed advisable. I found that the supplier maintained an extraordinarily close control over product quality. Raw materials were not just tested by batch. The variations within a strip had been found important; so the strip was chopped up and samples taken from every section. The standard practice in tooling was to cut the blueprint tolerance by

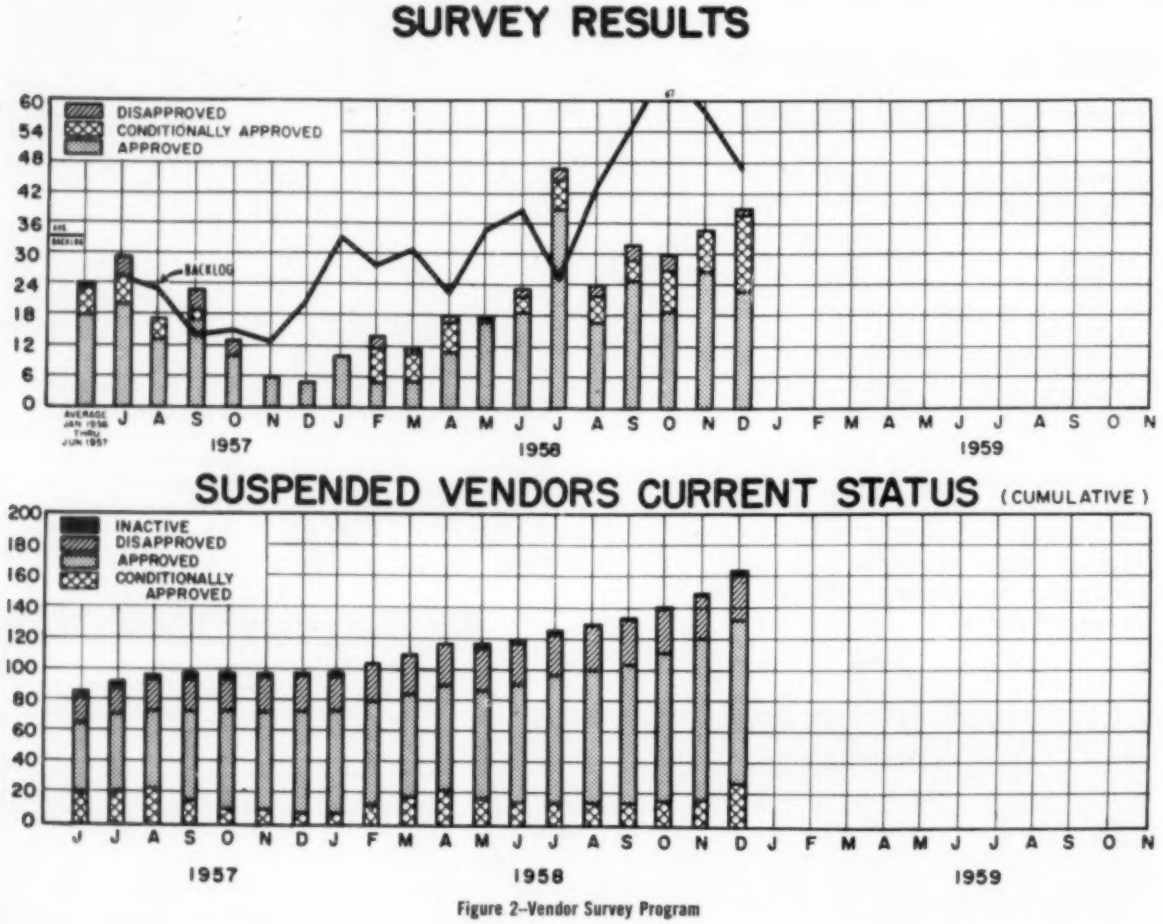


Figure 2--Vendor Survey Program

a factor of ten. This insured against process variations and a build up of tolerances affecting the operation of the device. Each group of machinists was under a group leader who maintained a constant check on output with gages that were calibrated every shift. This sort of thing was true throughout the operation. It was tight in-process control justified by the nature of the product. It happened that the company was so determined to make everyone in the place feel a personal responsibility for his output that they did not have one person labelled inspector or tester or quality engineer. It was the lack of familiar labels that upset the survey team.

Requirements and Vendor Tests

From sampling through ratings to surveys we have moved back into the time cycle of procurement and closer to the source of quality. Now the question comes up, how clearly have we told the supplier what we want? Often an honest look at the cause of serious trouble with purchased material shows something lacking in the statement of requirements. An aircraft industry survey revealed that many agreed this was a problem.[7] The electronics industry has also recognized the need for clear acceptance agreements.[8]

Sometimes the problem is with blueprints and specifications. Here the quality engineer can use case histories to prove to designers what details must be included. Too often "standard practice" and "good workmanship" are cover-ups for sloppy thinking. It also seems wise to tell a supplier what hurdles are planned for his product. Here I have run into occasional reluctance on the part of inspection people. One stand is that the purchase order should not say he can produce *any* bad parts. He must then make good on anything we find. The trouble with this is that the supplier will produce some percent of defective material no matter how hard he tries. Most suppliers will work to an Acceptable Quality Level, formal or informal. The trouble starts when the supplier assumes that 2 percent is all right when the buyer wants 1 percent. Telling the supplier what you want seems to apply to any procurement situation. It has been systematized for a mail order house buying garments,[9] in the high volume automotive industry[10,11] and for the extremely technical devices needed by the electronics and missiles industry.[12]

The latter involves a fully developed Vendor Quality Certification program and a major step in the direction of our idealistic objective that incoming inspection should be abolished. In one division alone the technique has been applied to more than 30,000 part numbers.

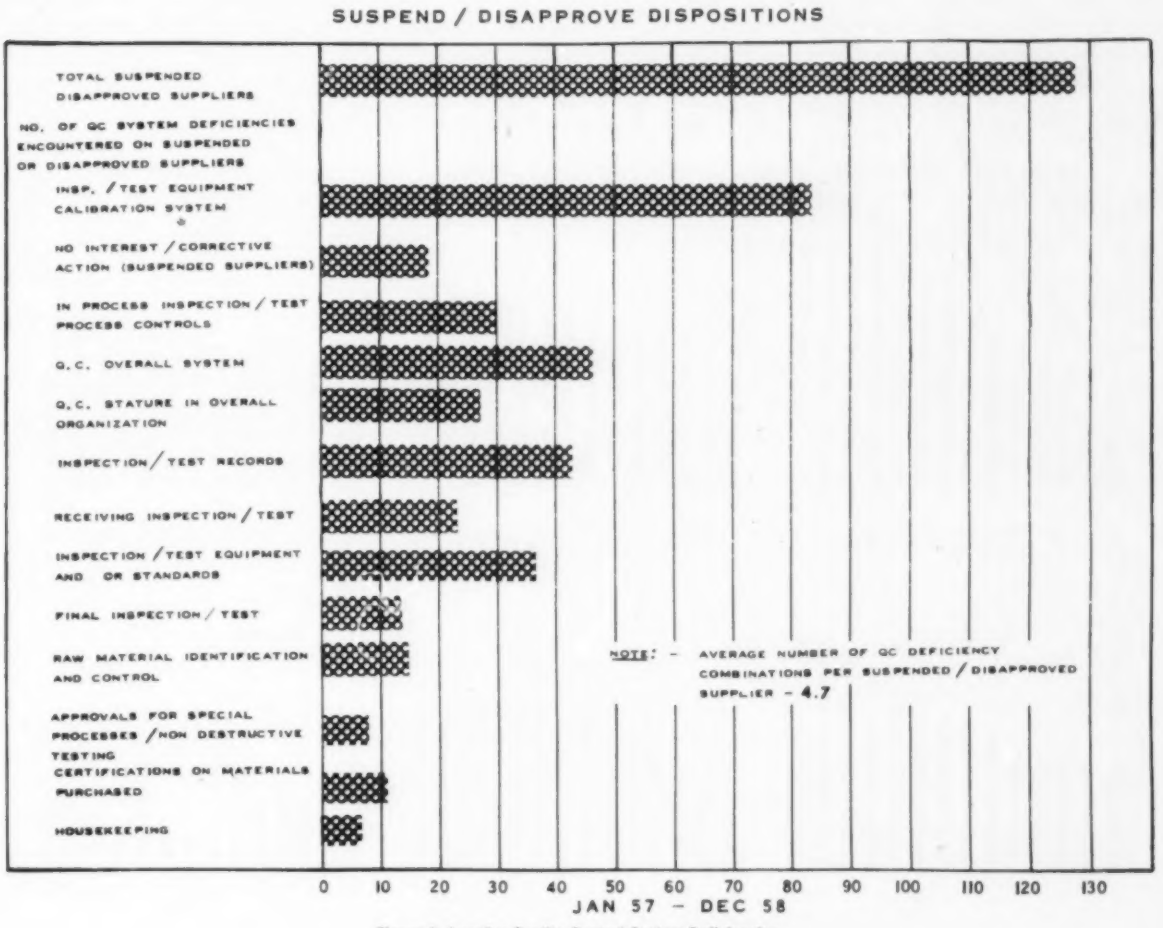

SUSPEND / DISAPPROVE DISPOSITIONS
TOTAL SUSPENDED DISAPPROVED SUPPLIERS
NO. OF QC SYSTEM DEFICIENCIES ENCOUNTERED ON SUSPENDED OR DISAPPROVED SUPPLIERS
INSP. / TEST EQUIPMENT CALIBRATION SYSTEM
NO INTEREST / CORRECTIVE ACTION (SUSPENDED SUPPLIERS)
IN PROCESS INSPECTION / TEST PROCESS CONTROLS
Q.C. OVERALL SYSTEM
Q.C. STATURE IN OVERALL ORGANIZATION
INSPECTION / TEST RECORDS
RECEIVING INSPECTION / TEST
INSPECTION / TEST EQUIPMENT AND OR STANDARDS
FINAL INSPECTION / TEST
RAW MATERIAL IDENTIFICATION AND CONTROL
APPROVALS FOR SPECIAL PROCESSES / NON DESTRUCTIVE TESTING
CERTIFICATIONS ON MATERIALS PURCHASED
HOUSEKEEPING
NOTE: - AVERAGE NUMBER OF QC DEFICIENCY COMBINATIONS PER SUSPENDED / DISAPPROVED SUPPLIER - 4.7
0 10 20 30 40 50 60 70 80 90 100 110 120 130
JAN 57 - DEC 58

Figure 3–Supplier Quality Control System Deficiencies

The growth of this activity in another division is charted in Figure 4. The Q numbers refer to purchaser order attachments. The supplier sends in with his shipments certified inspection and test data on a list of characteristics. He uses tests, procedures and sampling plans detailed in purchase order terms. In our business we have had to go beyond the relatively superficial "does it meet the blueprint at this moment?" kind of inspection. Performance under environmental stresses and the probability of surviving for extended operation are involved. Here the quality engineer has his work cut out for him. A set of requirements that provides ideal protection is generally impossibly expensive. He has to get the advice of the designers and use his own data to find what characteristics are the most important. A complete set of tests on a small sample for an electronic component can cost 5 to 10,000 dollars. This does not fit very well into an order for 500 parts at ten dollars each. There is plenty of room for ingenuity in designing test plans that make the best use of limited data.[13,14] It pays to get a supplier's views on the subject. His knowledge of his product may suggest an approach that will be effective and still cost less than the requirements we develop.

Aside from the expense of tests there is the increasing problem in the defense industry of stringent failure rate requirements. A contractor for a new missile system has been inviting bids with a requirement that electronic parts have a failure rate of 0.001 percent per thousand hours of operation. Try that one on anybody's sampling tables! It is equally obvious that 100 percent or 200 percent or 300 percent sorting cannot guarantee such figures. The quality engineer finds himself working with his brother engineers on the safety margin between inherent parts strength and the stresses imposed by application. He will have to dig deep into the causes of process variability.

We have already proved to our satisfaction that use of the Vendor Quality Certification approach can bring 10 to 1 improvements in material received and reduce incoming inspection's burden. Now we need the techniques that will bring much greater gains.

Let me hasten to say that the severe problems of weapons reliability are only an extreme case. The Vendor Quality Certification approach can be applied where no raising of quality standards is involved and the object is to maintain a satisfactory level with a minimum of wasted manpower, materials and time.

Problems of Qualification

When an order is placed for materials, the assumption is made that acceptable product received will be fully capable of meeting the user's needs. This applies whether the design belongs to the supplier or the buyer. In any industry where designs change or techniques are

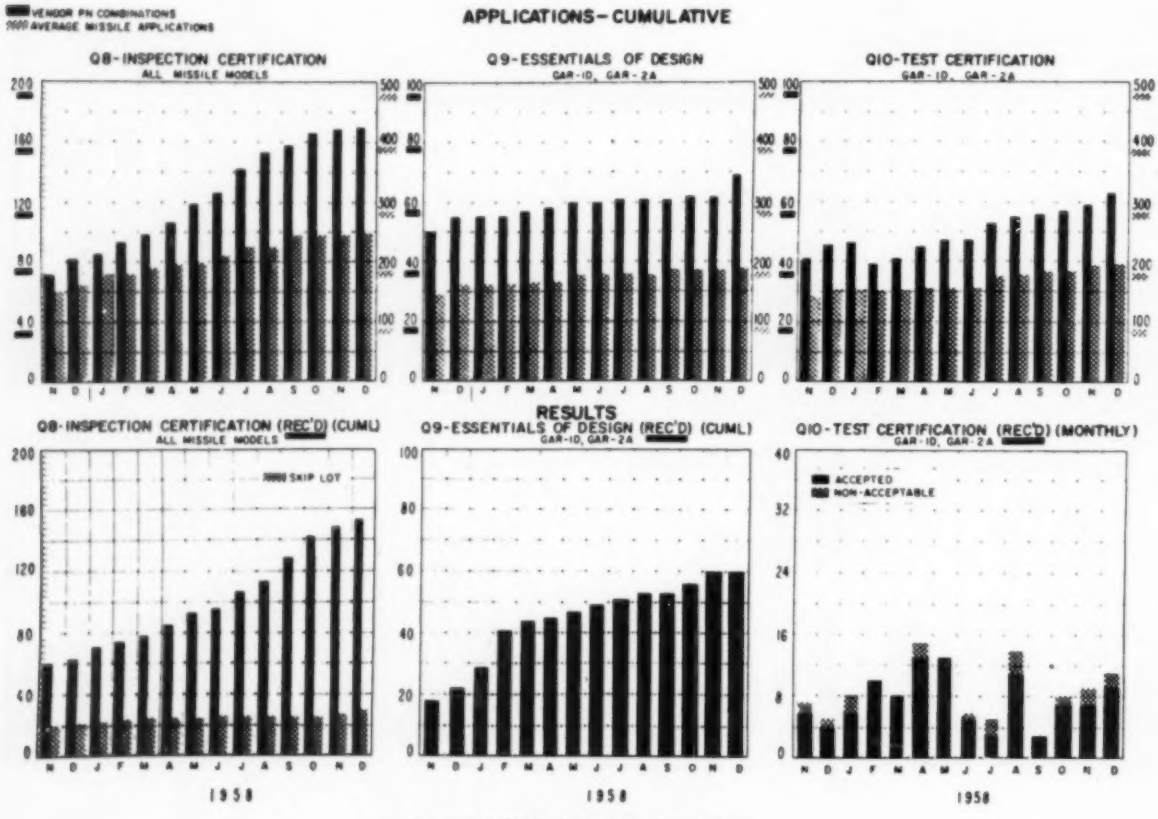
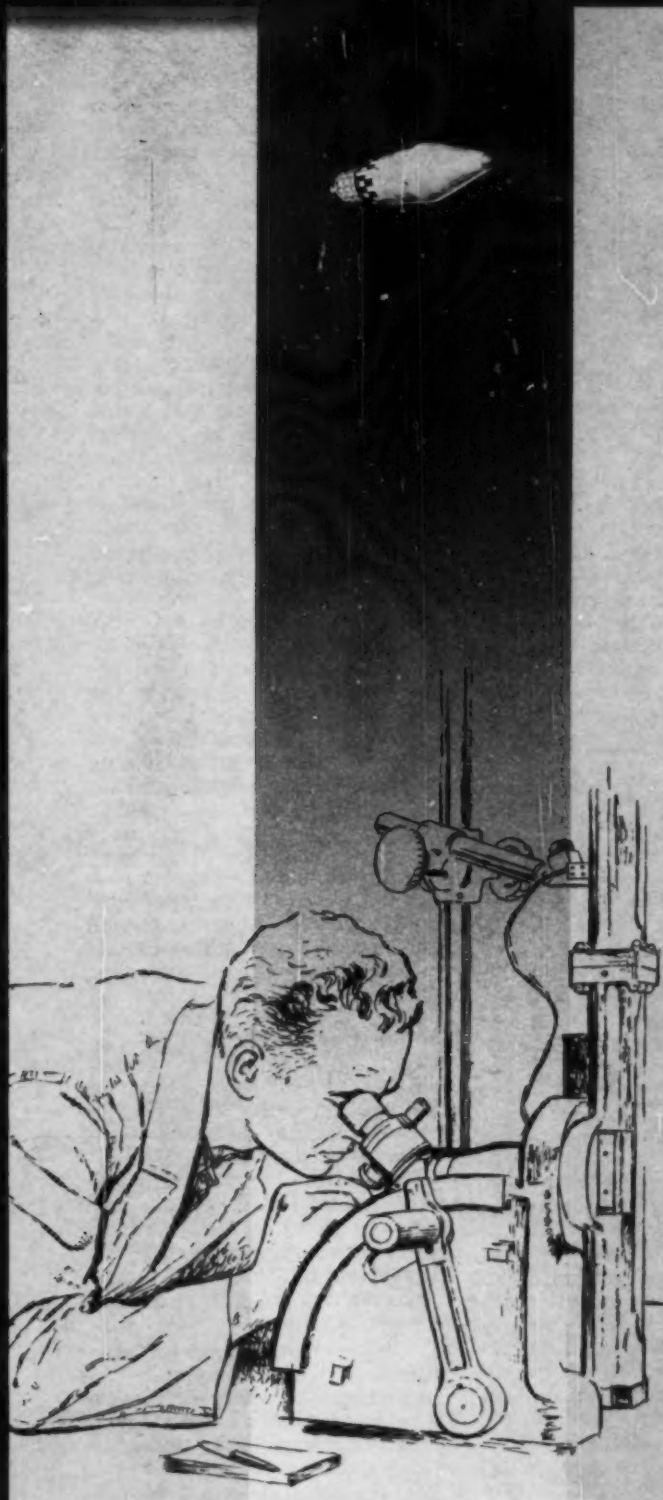


Figure 4–Vendor Quality Certification Program



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advancing, this often proves a dangerous assumption. The statistically-minded quality engineer knows the inadequacy of most design qualification practices. It is an area where his services have not often been invited. He struggles against the commonly held impression that quality control is only some fancier form of inspection to be applied during production. There is no use wishing this bias would go away of its own accord. The invitation will come only when he has made some practical demonstrations that the designer can spare himself embarrassing troubles and that management can cut avoidable costs by including in qualification practices the techniques needed to pin down the range of product variability. This is a cornerstone in the effort to reduce the need for incoming inspection.

Change Control and Quality

There is a second cause of trouble that also needs attention from quality people. This is change control. Changes may be made to reduce costs, to speed output or to improve performance. No matter what the reason, they tend to undermine the basis on which we may have built up confidence in a product. We see operating the well known scientific principle that if anything can go wrong it probably will. The buyer does not want to inhibit his source from making good changes or hamstring his effort with too much red tape. Sad experience has convinced more than one quality man that it is necessary to reach an agreement with the supplier that he will give notice of changes and provide evidence that it is beneficial, sometimes even to the point of complete requalification. The quality engineer is not trying to undermine the authority of designers to make changes. It is his business to see that they are introduced by a planned and controlled procedure that assures continuing product performance.

Opportunities for Quality Engineering

The approaches discussed so far have been aimed at bringing material up to the receiving dock with enough confidence in its quality that it can be forwarded directly into stores. This would get Old Ironlungs off the back of the Quality Manager. I am not a complete optimist, however. Such a millenium will not appear tomorrow, or the day after. The fast changing demands of our technical civilization will probably keep even the smartest quality engineer from being able to abolish inspection on all incoming materials. And as long as there is such an operation, quality engineers can find plenty of opportunities for their professional abilities. To suggest just two:

First, we hoot at designers for setting tolerances arbitrarily. Are not most Acceptable Quality Levels set the same way? Can we find a practical method of establishing a break-even point based on dollars and cents? E. L. Grant has outlined some of the difficulties and the factors we must think about when we attempt to work on a dollars and cents basis.[15]

Second, have we used statistical techniques to determine optimum lot sizes from a sampling, work-in-process inventory and overall cost viewpoint? The point is that there is more to the quality engineering world than "p" charts and operating characteristic curves. This was the approach advocated by the Professional Development Committee in the first draft of the Basic Work Elements of Quality Control Engineering.[16]

Summary

All of the methods mentioned have been tried by companies to different degrees and with varying success. Judging by our own experience it is very easy to underestimate the amount of education, persuasion and just plain patience that must go into making them effective. The quality engineer has to reach out in two directions. Internally the engineering, purchasing and other related groups must come to see that what he is doing really is constructive and helpful. Without their active interest the programs will not get off the ground. The numerous pitfalls involved in putting across any new Quality Control approach are a story in themselves and will not be covered here.[17]

When he has gained solid backing at home, the quality engineer must expect an equally difficult job with his vendors. Some of the ideas that appear so sound from his company's viewpoint will seem like interference and an unreasonable expense to suppliers. There is no substitute for skilled personal contact in this case. When a company has a large purchasing program and hundreds of suppliers, the contact can be supplemented in a number of ways. My own company has used brochures, technical reports, field trips and motion pictures to help put across the story. Groups of suppliers were given a "road show" in several cities across the country. We continue to invite suppliers to meetings held by the manufacturing divisions. They present the vendor program and specific case histories of the kinds of troubles we are trying to avoid. When a major item of equipment is to be subcontracted for design, quality control joins in the presentation made at a bidder's conference. This helps to get everyone off on an equal footing with better knowledge of what will be required.

Guide Lines for Planning

This discussion has emphasized the preventive aspects of quality control. I have borrowed an approach often stated by one of our manufacturing managers, "Someone should do something drastic." By adopting the drastic notion that incoming inspection ought to be abolished, perhaps we can lift our thinking out of the rut of routine. The point of view presented offers a challenge to original thinking.

There are many more possibilities than this paper has been able to suggest. In selecting from the various approaches that can be applied to the area of incoming material the following principles may help:

1. We cannot expect satisfactory material from an inadequate source. Quality Control has a large stake in improving the selection process.
2. The supplier cannot be held to account for requirements that are not defined. Furthermore, specified requirements that are not backed up by a means of enforcement are so many empty words on paper. It is quality engineering's job to make sure the statement of requirements is complete, to

design the means of enforcement and to arrive at a clear agreement with the supplier. This is a necessary service to both the engineering and procurement functions.

3. It is basic to Quality Control thinking that all controls are to be placed as close as possible to the source of variation. In the case of incoming material this means that controls maintained by the supplier will be more effective than efforts to control material after receipt. If we have done a good job of selecting a supplier, he should know more about how to control his own product than we do.
4. Purchasing has the difficult job of balancing out the factors of schedule, cost and quality of incoming material. The quality engineer can be most effective when he provides a sound, quantitative basis for making the necessary managerial decisions.

An underlying purpose of these proposals is humanitarian. I would like to spare the Quality Manager, and, yes, especially Old Leatherlungs, from too many unhappy Friday afternoons late in the month.

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Fifth District All Day Conference

The Fifth District All Day Conference will open at 9:30 a.m., Apr. 2, at the Hotel Yorktowne, York, Pa.

The luncheon topic, "The Engineer and Statistician Can Meet," will be presented by Miss Besse B. Day, Bureau of Ships, Department of the Navy, Washington, D. C., and F. R. Del Priore, USN Engineering Experiment Station, Annapolis, Md.

At other sessions Dorian Shainin will present, "Introducing Quality Into a Going Plant or Operation," and will also conduct a management seminar. Mr. Shainin is with Rath & Strong, Boston, Mass.

W. A. MacCrehan, Bendix Radio Division, Towson, Md., will discuss "The Challenge of Reliability," and will direct a section of the management seminar.

Ervin F. Taylor, The Martin Co., Baltimore, Md., will speak on "Discovery Sampling by Attributes."

Mason E. Wescott, Rutgers • The State University, New Brunswick, N. J., editor, *Industrial Quality Control*, will conduct a technical seminar on the "Use of Advance Techniques," and later, "A Careful Look at a Common Problem in Statistical QC — Correlation and Regression."

SUPERVISOR'S CIRCLE

PAUL A. ROBERT, *Editor*

Precision Products Co. of Cincinnati, Box 130, Norwood 12, Ohio

DETERMINING QUALITY COSTS

GLENN E. OWEN, Convair-Fort Worth
A Division of General Dynamics Corporation

Quality costs can be placed into three broad categories. These are—cost of inherent quality of the product, costs due to lack of quality and cost to assure and maintain quality.

The first of these—cost of inherent quality of the product—depends upon the design of the product. It is included as a part of the cost of engineering, tooling, manufacturing, overhead, facilities, materials, services, etc. The cost of inherent quality is based upon the complexity of the product—and today's products are certainly more complex than yesterday's. The trend toward "Functional Density" requires that manufacturers incorporate more and more function into less and less space. Performance requirements for the product limit its weight and size. Today's aircraft and missiles are filled with complicated electronics equipment and some of these vehicles use exotic fuels. Today's automobile is equipped with a powerful engine, power steering, power brakes, power windows, power seats and air conditioning.

Editorial Comments

There has been a lot written about measuring quality costs and most of us have yard-sticks appropriate to our industry. However, it is a subject worthy of repeated discussions because, as the author points out, the picture is constantly changing and what may have been a satisfactory base against which to project our quality costs may no longer be so.

Also, management has certain preconceived notions of what quality costs should be in relation to other costs. As these relationships change the quality manager should re-educate his management to these new trends in industry.

You should find this article by Mr. Owen quite thought provoking.

The second category of quality costs—costs due to lack of quality—consist of both tangible and intangible costs. Tangible costs, such as the cost of scrap and rework, can be measured and included as part of the overall cost of the product. Costs resulting from loss of business due to customer dissatisfaction and loss of prestige are usually difficult to measure and are therefore considered to be intangible.

The third category of quality costs—cost to assure and maintain quality—is the cost of quality control itself. This cost is normally expressed in terms of labor, facilities and overhead. It must be determined by and controlled by the quality control organization.

Determination of the quality control cost begins with the bid for new business or costing of a new product. After familiarizing itself with the new product and the associated program requirements, the quality control organization should prepare a time-phased plan of action. This plan will establish what has to be done, how it will be done and when it will be done.

An incremental breakdown of the quality control task should then be accomplished. This will permit isolation of any tasks requiring new or advanced quality control methods, techniques or facilities. Such tasks are normally governed by advanced technology, i.e. product complexity and functional density—and customer procurement requirements or policy. The difficulty of accomplishing these tasks is influenced by the state-of-the-art in manufacturing and quality control as compared with the state-of-the-art in design. Each of the new or revised tasks must be analyzed in order to decide upon the best method of determining the cost.

Several methods of determining quality control labor costs may be used—many companies use a ratio to direct manufacturing labor hours. Ordinarily these ratios are derived from past data. Therefore, when this method is used it will be necessary to adjust the ratios to compensate for the aforementioned new or revised tasks. For example, some of today's aircraft are constructed of larger components through application of new adhesive bonding, brazing and chemical etching processes. While fewer manufacturing personnel are required to build these components, the quality control task is significantly increased. Sonic testing, x-ray, fluoroscopy and some destructive testing are required for the components. Control of raw material through acceptance and production testing requires extensive application of advanced chemical and metallurgical techniques. Control of critical characteristics of solutions, equipment, raw materials and components during manufacturing processes requires careful scrutiny by quality control.

Also, machining of parts by numerical control methods requires far fewer manufacturing personnel than conventional machining methods, yet quality control must inspect the same number of parts for more critical characteristics.

Needless to say, advancing technology imposes closer and closer tolerances in all phases of manufacturing which obviously add to the quality control task. Also, more and newer types of electronic equipment require additional testing and closer inspection on the part of quality control.

Other costing techniques utilize manhours per operation, cost per piece or article and per-

cent of some base such as total manufacturing cost. A combination of all the foregoing techniques may also be used.

Customer procurement requirements or policy must be evaluated by quality control in order to determine their influence upon the quality control task and costs. Such requirements may be imposed through specifications or contractual clauses. Additional quality control costs due to customer procurement policy may be illustrated by referring to the Weapons System Concept for military products. This concept increases the prime contractor's area of responsibility and lengthens his lines of communications. It significantly increases the number of subcontractors and vendors with which the prime contractor must work.

The quality control organization must also evaluate its facilities requirements in the light of technological advances. New non-destructive testing requirements may require the procurement of sonic and fluoroscopic devices. Control of the physical properties of new raw materials and the control of new manufacturing processes may require special metallurgical and chemical laboratory equipment. Closer tolerances may require advanced gaging devices. Critical characteristics of electronics components may require special test equipment. Since such facilities are more expensive the quality control organization must assure that optimum quantities are ordered.

In cases where indirect costs are established on a rate basis to direct costs, the quality control organization must isolate and analyze any effects which new or revised direct tasks impose on the indirect rates. Rates must then be adjusted accordingly. Training costs may require such an adjustment.

Once the bid is made and the contract obtained—or in the case of commercial products, the company decides to market a new product — quality control must establish cost and budgetary controls. In many cases the bid becomes the budget. The quality control organization may distribute its budget to its organizational elements and require each element to maintain its own controls.

Continuous redetermination of Quality Control costs is necessary from this point on. These costs must be adjusted and forecast for each subsequent financial period. Adjustments will include corrections for errors in the original bid or savings realized from improvements in or efficiencies gained by the Quality Control System.

To effect improvements, efficiencies and resultant savings; the quality control organization must constantly strive to balance the optimum degree of quality control actually required against the risks involved. To do this, quality control management must effectively utilize the quality control engineering, statistical and scientific elements of the quality control organization in conjunction with good management judgment.

Quality control management must then measure these savings after which it can determine the net cost of quality control—predetermined costs minus the savings realized from improvements made and efficiencies gained.

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BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

ANALYSIS OF STRAIGHT - LINE DATA, by Forman S. Acton, xiii plus 267 pages, published by John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., London, price $9.00. Reviewed by Martin Fox, Michigan State University.

This book is written for scientists and engineers with a good statistical background preferably including analysis of variance. Throughout the book the importance of the choice of the mathematical model is stressed. Thus, a person with the necessary statistical background who knows what he wants to do and who has a clear idea of which of the models in the book is most appropriate, can find the tools he needs. Heavy stress is placed on various kinds of confidence limits and the kind of confidence statements appropriate to each.

The linear models and their analysis are handled in chapters one through six. Chapter seven deals briefly with the use of orthogonal polynomials with a quadratic (or any polynomial) model. The remaining three chapters deal with outlying observations, and cumulative transformations of data, elimination of data. Tables of critical values for the statistics used are given.

The chief criticism of this reviewer is directed at chapter nine, The Rejection of Unwanted Data. In this chapter the author presents tests of the hypothesis that a given observation is not an outlier. It is the opinion of this reviewer that outliers cannot be eliminated on the basis of any statistical test, but only on the basis of knowledge that the experiment ran wrong. Of course, one should not only examine experiments in which outliers occur, but such an examination should be made of every experiment prior to any examination of the data.

There is one other important criticism to be made. On page 43 the author gives the impression that there is something illigitimate about obtaining confidence limits for fixed but unknown quantities. However, the theory of confidence intervals was developed for the estimation of these fixed, unknown quantities. In this book legitimate confidence limits are given both for fixed quantities and for random variables yet to be observed.

There are a few instances of rather sloppy writing in the book. These instances are exemplified by the statement ". . . where ϵ_i is an independent random variable . . ." which appears on page 91. Fortunately such instances are rare.

The author's verbal style is excellent and in some places is delightfully humorous. A careful reader who has the necessary background and who is forewarned about its shortcomings should find this book useful when one of the models contained in it is appropriate.

MATRIX CALCULUS (Second revised and enlarged edition) by E. Bodewig, Interscience Publishers, Inc., New York, 1959, 452 pages. $9.50. Reviewed by Ingram Olkin, Statistics Department, Michigan State University.

This book is a very useful and readable one and the casual reader should not be misled by the title or preface. There is a wealth of results, of both theoretical and practical nature, which provide a very handy reference. Although the book is designed to be self-contained, it will be of greatest value to those already familiar with computational problems involving matrix methods.

The contents are divided into four parts, matrix calculus, linear equations, inversion of matrices, eigenvalue and eigenvector problems. In the first part, the author introduces his notation which deviates somewhat from the more conventional notations. However, it is standard enough, so that the reader does not have to labor to become accustomed to the modifications. In addition to giving an introduction to matrix theory, there is a compendium of extremum properties for eigenvalues and for the determinant.

The remainder of the book deals with the main problems confronting the computer, that of solving linear equations, inverting matrices, and determining eigenvalues and eigenvectors. It is a rarity that a single method will offer a useful method of solution to any of these problems for all cases. The author discusses a number of methods, broadly classified as "direct" or "iterative" methods, including many variants in each category. Thus, for example, under direct methods for solving linear equations, there is a discussion of exact and approximate methods, with a section on ill-conditioned equations; in the section dealing with iterative methods for eigen problems, there is a subsection dealing with the case when the dominant eigenvalue is real. An effort is made to cater to methods appropriate for both mechanical and electronic computers, with comments on the number of operations involved. To aid the reader in the choice of techniques, there are numerous remarks, conclusions and summaries which point out the restrictions and advantages of the particular procedures.

Some references are given in footnotes and others in the Bibliography. It would be more useful if all references were included in the Bibliography. However, the Table of Contents and Index are sufficiently detailed, so that the reader who wishes to locate a reference can easily do so.

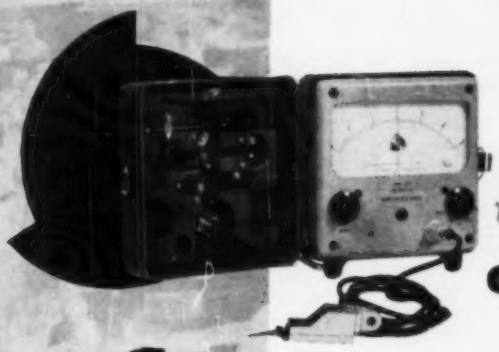
Clifford A. Wallace Retires from Eastman Kodak

Clifford A. Wallace, director of quality control for the Apparatus and Optical (A&O) Division, Eastman Kodak Co., has retired from the company after 41 years of service.

The A&O Division includes three plants in Rochester, N.Y.—the Camera Works, the Hawk-Eye Works, and the Lincoln plant—which manufacture cameras, projectors, and other photographic and optical equipment, and special military products. Mr. Wallace has been director of quality control for the Camera Works since 1940 and for the A&O Division since it was formed in 1956.

Mr. Wallace joined the Camera Works in 1918 as a member of the methods department and in 1926 became sub-foreman of the process engineering department. The following year he moved to the production planning department, where he became assistant to the department head. In 1926 he was appointed head of the final inspection department and in 1932 assistant superintendent of quality.

An ASQC Fellow, he is also a member of the Institute of Mathematical Statistics, the Photographic Society of America, and the Rochester Chamber of Commerce. He is a member at large of the Otetiana Council of the Boy Scouts of America, with whom he formerly served as Rochester area commissioner.



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What's New?

ROY A. WYLIE, *Editor*
Ampex Corporation

P-3-2—The Pyro Model No. 107 Optical Pyrometer Calibrating Set has been designed as a versatile and precise unit which will permit the accurate and simultaneous calibration of any two Optical Pyrometers, irrespective of manufacture. It is furnished as a packaged set ready to use and complete with a Certificate of Calibration. A wide filament strip type lamp can be adjusted by step and vernier rheostats to any desired temperature in the range from 1400 degrees F. to 4200 degrees F (800 degrees C to 2300 degrees C). Suitable instrument holders and brackets are furnished to permit the mounting of different types of Optical Pyrometers. The Test Set eliminates uncertainties and provides an accurate and easy method for calibrating all types of optical pyrometers in the field.

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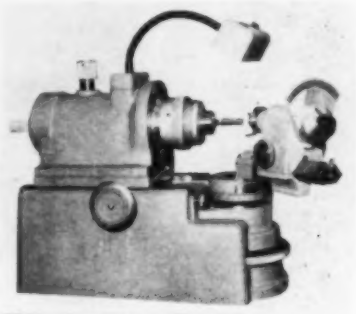

P-3-3—Stocker & Yale have introduced an improved version of their Tap Analyser. Originally intended for inspection and qualification of taps, the new tool analyser will accommodate many other small tools including drills, reamers, broaches, counter bores, hobs, etc. The measuring system incorporates a monocular, zero-paralax optical system with magnifications up to 40X. The tool to be inspected is accurately chucked in relation to index, view angle and dimensional scales. Readings to 0.0001 inches may then be taken. All readings are made at one setting—thus eliminating transfer errors. Shank tools are referenced on the shank in the manner in which the tool is used. Tool geometry may be related to production results, affording more positive quality control. The Tool Analyser will accommodate shank diameters from 0.006 inches to 1-3/8 inches with standard equipment, and provision has been made to remove the regular chuck head for replacement by special fixturing (V blocks, center supports, clamps, vises, etc.). Thus, the range of the instrument is further increased, and tools or workpieces without shanks may also be observed. A full complement of accessories including collets, chucks, arbors and outics are interchangeable so that many tool sizes can be accommodated.

* * *

P-3-4—The new model of Waters Torque Watch Gauge for measuring torque accurately has several new features. The body, is flatted on six sides, thus permitting the hand to get a better grip on the top of the instrument. The hexagonal body also provides an "anti-roll" feature when the Torque Watch Gauge is resting on its side, or provides a better mating surface for any adapters that the customer may wish to apply. An-

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other feature of the new Torque Watch Gauge is the "memory-needle", which permits readings to be taken in the dark, since the needle will "remember" the highest torque applied to the gauge. Torque may be measured by slipping the chuck of a Torque Watch Gauge over any shaft up to 1/4 inch diameter and reading the starting and moving torques accurately to within ±5 percent directly on the large dial (±2 percent on special order). Torque Watch Gauges are available in clockwise, counter-clockwise or bi-directional models in ranges from 0.005 to 40 ounce inches and 2 to 2400 gram centimeters.

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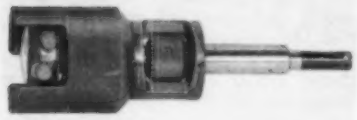

P-3-7—An addition to their line of hole location and concentricity gages is announced by Mayes Tool Co. The new model CC-100-V has the indicator axially centered and recessed in the head of the gage so that the indicator is read directly in line with the hole being checked. Reading of the indicator when checking holes at bench level is also facilitated. Like other Con-Chek gages in the line, the ground and lapped pilot member remains stationary in its locating hole, while a knurled thumb knob is rotated to actuate an indicator finger that checks runout on the other hole. Wear on the pilot is virtually eliminated.

* * *

P-3-8 — The Ameresco Model T-1 Precision Electrical Thermometer is a compact and simple to use instrument designed for quick determination of surface and immersion temperatures in either laboratory or production line applications. The Model T-1 has the advantage of operating through a handy probe 1/2 inch in diameter and 7 inches long, connected to the instrument body and meter by means of a thin, 5 conductor cable approximately 30 inches in length. The operator has only to touch (or immerse) the probe to the object or substance whose temperature he wishes to measure and simultaneously read the temperature from the meter. The instrument has a range of from minus 20 degrees C to plus 180 degrees C and is accurate to plus or minus 1 to 1-1/2 degree C. The applications of the Model T-1 include determination of surface temperatures of electronic components; determination of engine and bearing friction temperatures, in chemical process industries for

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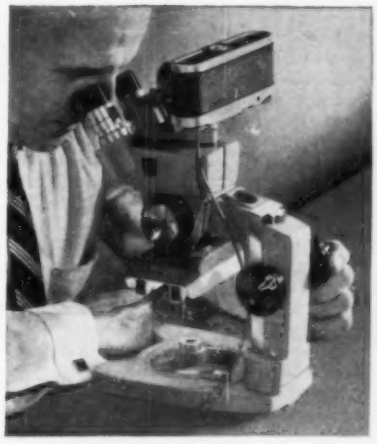

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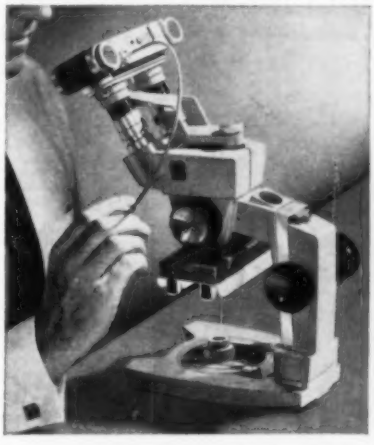

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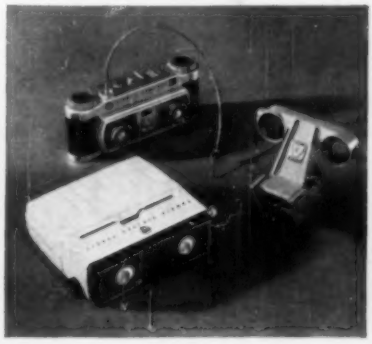

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checking gasses and liquids and in applications where heat distribution in cooling assembly designs is an important factor and where adherence to minimum or maximum temperature ranges in the manufacture of parts and materials is required.

P-3-10—The Terriss Inspection Light is now available for visual inspection of bottles and containers in production line filling assemblies. This light may be mounted on a conveyor for instant detection of broken, cracked, chipped or dirty bottles and containers. In liquid and dry packaging, it can detect the filling line level as well as foreign objects in empty plastic container or liquid filled plastic containers. The light offers the operator a full top view of the neck as well as the complete bottle or container. For semi opaque brown or amber colors, special new sodium vapor lights can be furnished. Lights are available in 18 inch, 36 inch, and 48 inch lengths with or without spot magnifying lens. Processing speeds of 60 to 300 units per minute are possible dependent upon the size of the light selected.

* * *

P-3-6—The Security Electronic Sensing Control recognizes metallic and nonmetallic objects without physical contact as they enter a capacity field. The model 400 is recommended where switches are impracticable. It consists of a sensing element or probe of any form or size, connected by coaxial cable to the electronic control. The device can be set up to any given constant at a given time interval. The unit then recognizes errors or deviations from the constant, as objects enter the field, and it indicates whether the sensed objects are too large or too small, too far or too near to a predetermined position or setting. Detection is expressed in numerous ways, such as stopping a machine, actuating a rejecting or correcting device or signaling for action by an attendant. Suggested uses are detecting variations in flow of material in a chute; revealing changes in moisture content of grain, flour, feeds, cereal, gypsum, etc., indicating changes in liquids flowing through a pipeline; testing for presence of foreign substances in fluids; discovering undesirable areas in continuous strip material (i.e. readymade adhesive bandages, gauge products, textiles, sanding belts); signaling improper nesting of blank in press die; revealing broken tools on automatic drilling and tapping machines; counting products in closed cartons; sensing missing caps on filled bottles prior to packaging; controlling position of cans on conveyor prior to filling operations; sizing and measuring parts and products on conveyor.

* * *

New Literature Available

L-3-1—A new bulletin describing the Kentron Micro Hardness Testers has been announced. These instruments apply dead weight loads from 1 to 1000 grams. Additional weights for applying heavier loads up to 10,000 grams can be furnished as optional equipment. Photographs and detailed descriptions of 10 basic accessories are also included in this bulletin.

* * *

L-3-2—SIE Model T-1A Vibration Meter, designed for accurate measurement of the velocity, displacement amplitude and acceleration of vibration, is described and illustrated in a bulletin. Specifications and applications for the battery powered unit are given.

* * *

L-3-3—A 4-page bulletin describing their new Electronic Solution Controller is available from Electro Mechanisms Corp. The unit is designed for automatic control of concentration of caustic, acidic or aqueous solutions in either continuous or batch-type metal washing equipment, plating processes, chemical process systems, textile bath equipment, and other applications where precise concentrate levels must be maintained.

* * *

L-3-4—A new 36-page catalog describes and prices the complete line of units designed and built by Nuclear Measurements Corp. Included are proportional counters, scalers, pulse height analyzers, universal shields, monitoring systems, portable survey meters, counting ratemeters, well counters, and medical laboratory instruments.

* * *

L-3-5—A complete line of Torquometers and Indicators - with individual models designed to satisfy specific industrial measuring requirements in standard ranges from inch ounces full scale through 30,000 inch pounds full scale and high speed capability to 50,000 rpm are illustrated and described in two bulletins recently issued by B & F Instruments, Inc.

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(as of November 24, 1959)

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(as of November 24, 1959)

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(as of October 31, 1959)

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clinics, conferences, and courses

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. . . **5—Fourth Dayton Quality Control Conference, Biltmore Hotel, Dayton, Ohio; sponsored by the Dayton section, contact George A. Friesell, Dayton Air Force Depot (MDQ), Dayton 20, Ohio.**

. . . **14-18**—32nd Institute on Industrial Relations at the Hollywood Beach Hotel, Hollywood, Fla., sponsored by the National Association of Manufacturers.

. . . **23-24**—Tenth Annual Iron and Steel Conference at the Pick-Roosevelt Hotel, Pittsburgh, Pa., co-sponsored by the Metals and Ceramics Industry Division and the Pittsburgh section of the Instrument Society of America, contact R. E. Blackwell, Box 1346, Pittsburgh 30, Pa.

APRIL

. . . **2—Fifth District All Day Conference, Hotel Yorktowne, York, Pa., sponsored by the Harrisburg, Pa., section, ASQC.**

. . . **3-15**—Sixth Advanced Statistical QC Institute, contact Theodore A. Toedt, University of Connecticut, Storrs, Conn.

. . . **18-19**—Third Annual Conference on Automatic Techniques, sponsored jointly by ASME, IRE, and AIEE, at the Cleveland-Sheraton Hotel, Cleveland, Ohio, contact the Publicity Chairman, Room 530, 1213 W. 3rd St., Cleveland 13, Ohio. Session II, Apr. 18, will cover Automatic Inspection and Quality Assurance.

. . . **20—Sixteenth Annual QC Conference at the University of Rochester, sponsored by the Rochester section, ASQC, contact C. Robert Stumpf, publicity chairman, Eastman Kodak Co., Kodak Park Works, Film Testing Division, Bldg. 6B, Rochester 4, N.Y.**

MAY

. . . **9-13**—1960 Castings Congress and Exposition, Philadelphia, Pa., sponsored by the American Foundrymen's Society, contact Denham & Co., 925 Book Bldg., Detroit 26, Mich.; telephone WO 5-4941.

. . . **16-18**—Symposium on Statistical Methods in the Pulp and Paper Industry sponsored by the Finnish Paper Engineers' Association in Helsinki, contact Nils J. Lindberg, general secretary of the symposium, the Finnish Paper Mills Association, Helsinki, Finland.

. . . **24-26—14th Annual Convention and Exhibition of the American Society for Quality Control, Hotel Sheraton-Palace, San Francisco, Calif.**

. . . **26-28—Third ASQC Workshop-Seminar, Management of Quality Control, Sir Francis Drake Hotel, San Francisco, Calif., see announcement, page 10, this issue, contact the Third ASQC Workshop-Seminar, ASQC, 161 W. Wisconsin Ave., Milwaukee 3, Wis.**

. . . **30-31, June 1—Mid-Pacific Conference, Honolulu.**

JUNE

. . . **6-10**—Tenth Annual Program of Quality Control for the Graphic Industries, Rochester Institute of Technology, Rochester, N.Y., contact Harold M. Kentner, Extended Services Division, RIT, Rochester 8, N.Y.

. . . **7-17**—Second Annual Short Course on the Design of Experiments, Charles R. Hicks, instructor, and a concurrent Advanced Short Course in Quality Control, Irving W. Burr, instructor, at Purdue University, contact Mr. Hicks or Mr. Burr, Purdue University, Lafayette, Ind.

. . . **13-24**—Two University of Michigan Engineering Summer Conferences: Models and Simulation in Operations Research, and Foundations and Tools for Operations Research and the Management Sciences, contact R. E. Carroll, Engineering Summer Conferences, University of Michigan, College of Engineering, Ann Arbor, Mich., telephone NOrmandy 3-1511, Ext. 2079.

. . . **13-30**—Two sessions of the 17th annual Statistical QC Program for the Chemical Industries, Rochester Institute of Technology, Rochester, N.Y.; 1st session—June 13-20, 2nd session—June 23-30; Applications Seminar—June 21-22, contact Harold M. Kentner, Extended Services Division, RIT, Rochester 8, N.Y.

. . . **19-25** and Aug. 7-13—Institute for Practical Research on Operations, contact Theodore A. Toedt, University of Connecticut, Storrs, Conn.

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May 24-26, 1960	**San Francisco**
May 22-24, 1961	**Philadelphia**
May 23-25, 1962	**Cincinnati**
May 20-22, 1963	**Chicago**
May 26-28, 1964	**Buffalo**

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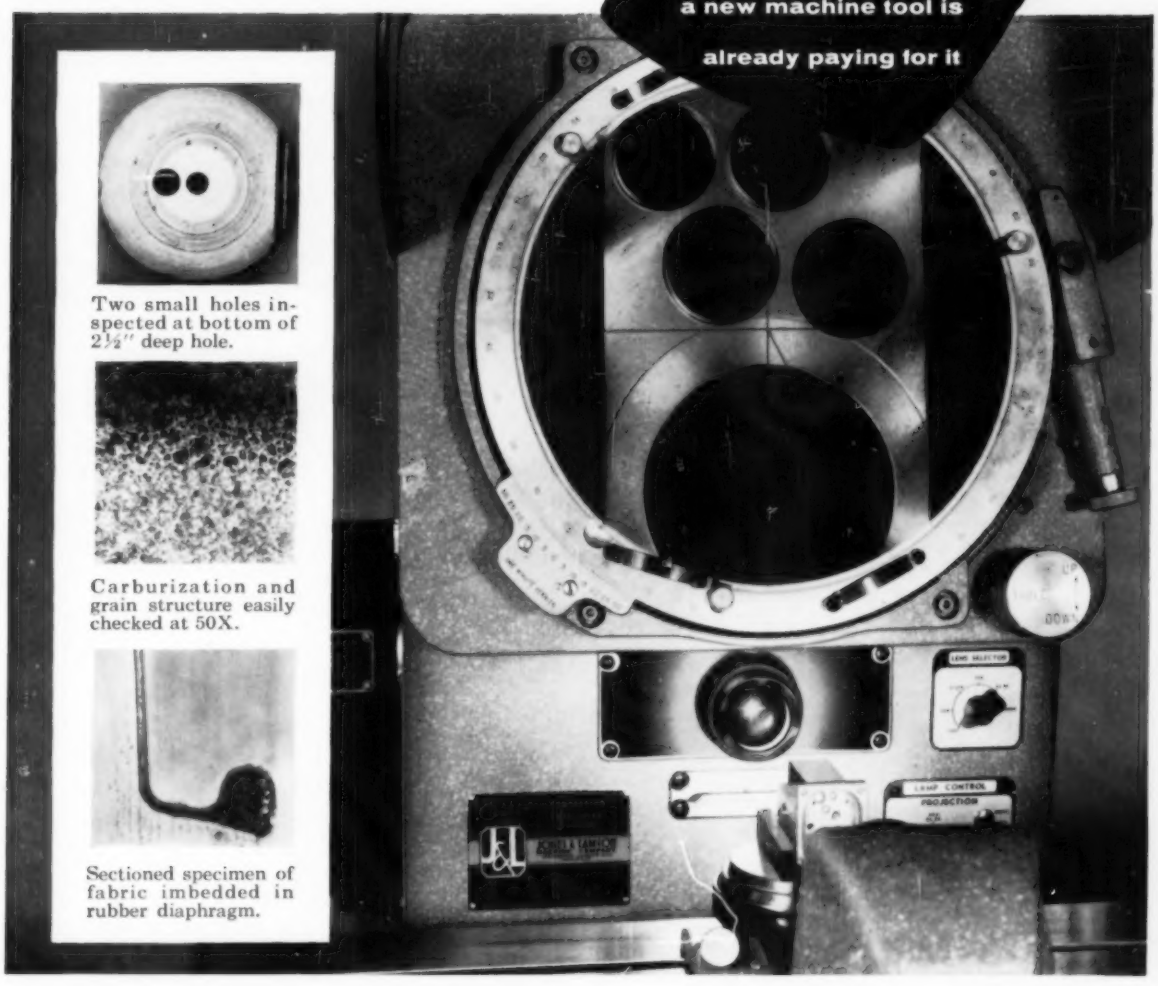

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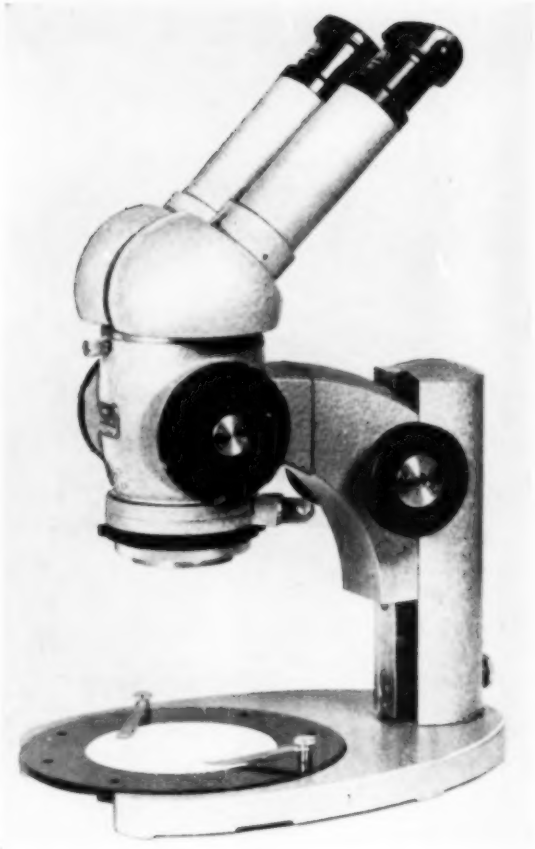

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